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IBM 1130 Computing System Component Description

IBM 2250 Display Unit Model 4

This publication contains detailed information about IBM 2250 Display Unit Model 4 programming, operations, and special features. The material is presented with the assumption that the reader has read the IBM 1130 Functional Characteristics, Form A26-5881.

The 2250-4 is a programmable display unit that attaches to the 1130 via a storage access channel. It can display lines, points, and characters, under control of a display program in 1130 main storage. Character generation is a program function, giving the user complete flexibility in the generation and use of character sets. Storage addressing and display program decoding and execution are performed by the 2250. A fiber-optic light pen, in conjunction with the display program and the logical capabilities of the 2250, enables the performance of computer-aided graphic design operations by the 2250 operator. Two special features, the alphameric keyboard and the programmed function keyboard, facilitate (1) message entry and editing by the 2250 operator and (2) communication between the 2250 operator and the CPU program.

First Edition

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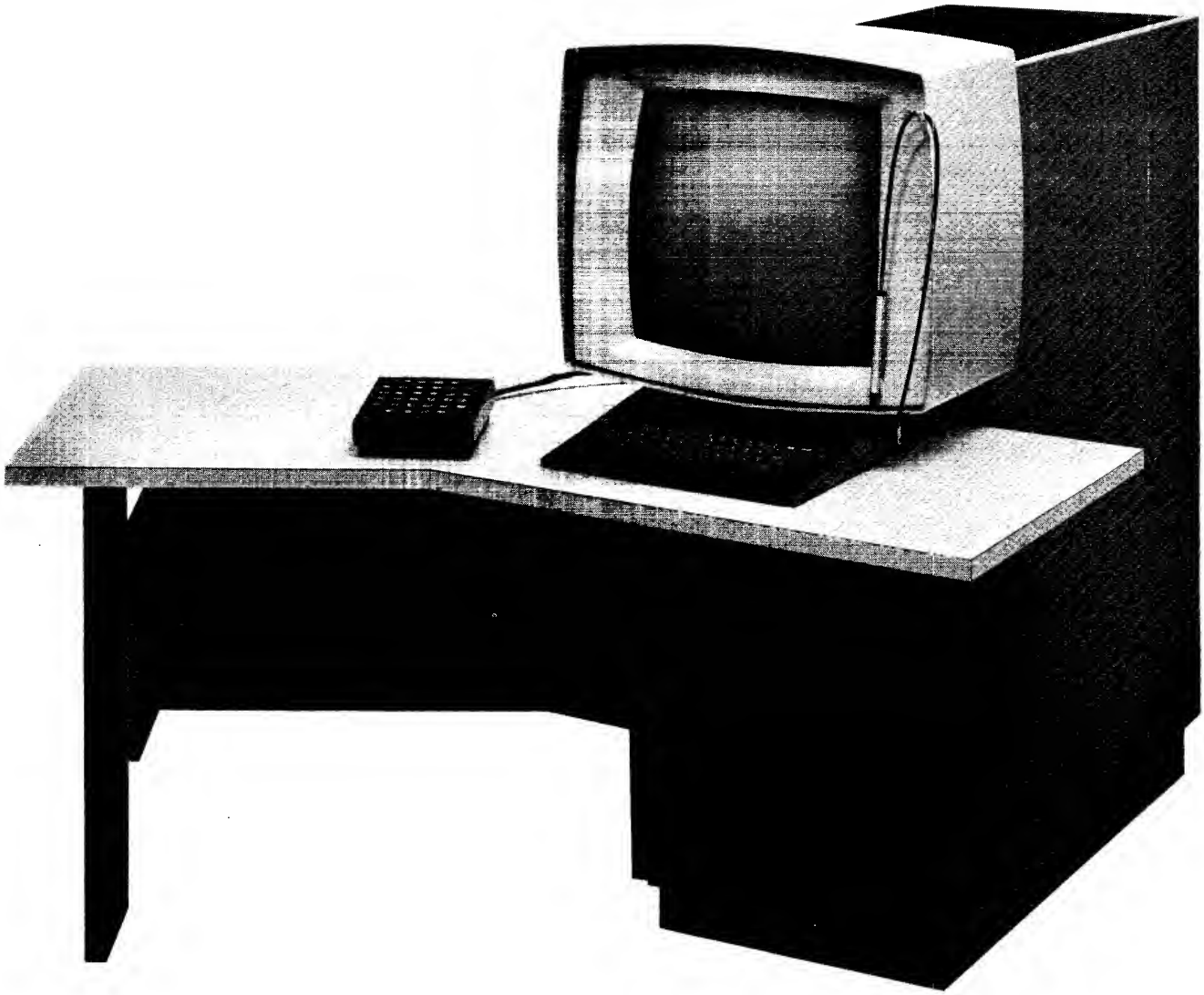


IBM 2250 Display Unit Model 4

The IBM 2250 Display Unit Model 4 (Frontispiece) is a programmable device which attaches to the IBM 1130 computing system and operates under control of a stored program in the 1131 Central Processing Unit (CPU). Two basic 2250-4/1130 system configurations (Figure 1) are available to supplement IBM's display products: (1) a stand-alone configuration, in which the 1130 is the host processor, and (2) a remote configuration, in which the 1130 attaches to IBM System/360 via the 1130 synchronous communications adapter and an IBM 2701 Data Adapter Unit.

The remote configuration, which enables installation of the 2250-4 at a location remote from the System/360, provides a user situated distant from the central computer convenient access to powerful graphic data processing facilities. In this configuration, the 1130 can function as a dedicated graphics processor, performing unique graphic functions such as light-pen tracking, image selection, and display manipulation. In addition, the central computer would be used for computational operations and for access to large data bases. Thus, the 1130 can (1) respond rapidly to display and conversational functions which, by virtue of their association with the user require fast response (in milliseconds), and (2) refer the computational functions for which the user can tolerate significantly

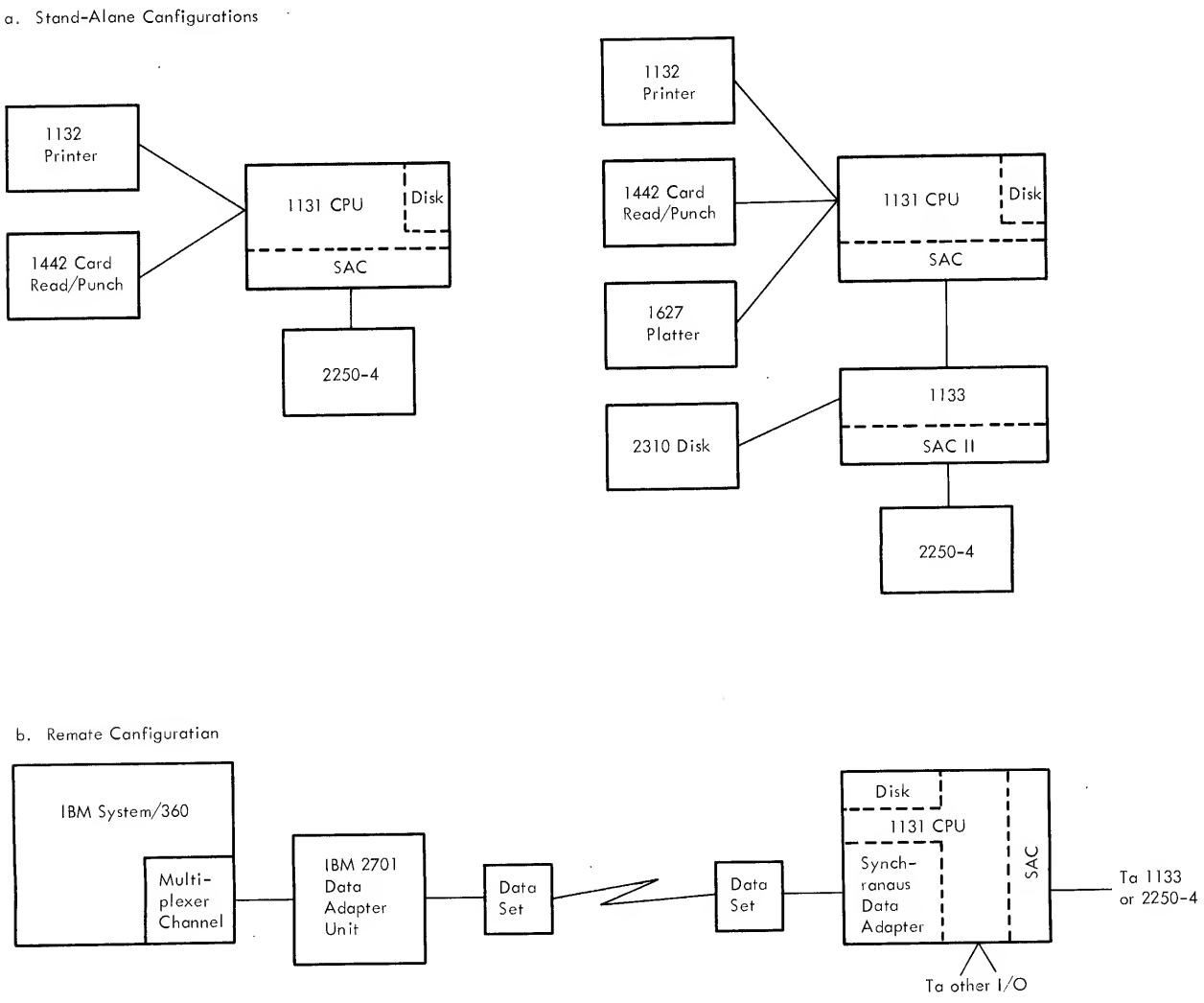


Figure 1. Typical 1130/2250-4 System Configurations

longer delays (in seconds or minutes) to System/360 for execution.

The stand-alone configuration is a low-cost graphic data processing system which makes the advantages of graphic data processing available to more users. In this configuration, the complete graphics application, including unique graphic functions and computational operations, can be performed by the 1130.

In either configuration, the 1130 can function as a general-purpose computing system. It is available with a variety of input/output (I/O) devices and with comprehensive programming support.

The 2250/1130 system offers fast man-machine communication and direct program control. The user can communicate with the computer in his natural technical language during execution of his problem. Logical capabilities in the 2250 enable the CPU program to effectively interpret user actions in connection with displayed images. In addition, the 1130 performs fast interrupt processing, and CPU processing can be overlapped with display program operations. Thus, the combined 1130 and 2250 form an effective and balanced graphic processing system.

The 2250-4 is a sit-down cathode-ray tube (CRT) display console for a single user. In addition to displaying graphic and alphameric information, the 2250 offers man-machine interaction through its light pen (standard feature) and two keyboards (special features). Using these facilities, a programmer can furnish computer-aided design capabilities whereby the 2250 user can create, modify, and add graphic and alphameric data into the system through the display screen.

The 2250 attaches to the 1130 via a 1130 Storage Access Channel (SAC or SAC II) as shown in Figure 1. The 1130 operates and controls the 2250 through commands and through a display order program sent from CPU storage to the 2250 via SAC. A display program comprising a series of orders (intermixed image and control information) can be sent to the 2250 up to 40 times a second (25ms frame time). This arrangement enables 1130 and 2250 operations to be asynchronous. Once 2250 operations have been started, the 2250 addresses CPU storage as required to execute the display program, stealing memory cycles from the CPU without CPU program intervention. In the 1130 system, I/O devices have higher cycle-stealing priority than the CPU; thus, memory-cycle demands by the 2250 always have higher priority than those of the CPU program. Note that 2250 cycle-stealing is prevented from causing significant interference with other 1130 I/O device operations; devices that operate synchronously with the CPU are assigned higher priority than the 2250 to eliminate 2250 interference with synchronous operations.

Images in the form of alphameric characters, straight lines, and points are displayed on the 12-inch by 12-inch area of the CRT screen. This display area is divided into a 1,024X-by-1,024Y position grid. Points can be plotted at any intersection on this grid, and straight-line segments can be drawn between any two intersections; absolute and incremental positioning can be specified by image information from the display program.

Character generation is a programmable function, giving the user complete flexibility in the generation and use of character sets. Characters represented by their component strokes are stored as subroutines in CPU storage. In addition, the capability to subscript and superscript characters is provided. These capabilities are particularly important in scientific applications that require the display of special symbols (such as Greek alphabetics). Inherently upper and lower-case is part of this programmable character set feature.

The fiber-optic light pen provided, together with the logical capabilities of the 2250, enable the user to identify elements of displayed data to either the display program or the CPU program. Light-pen operations are enabled and controlled by the display program. The user can identify an element either by pointing the light pen at the element and causing depression of the tip switch at the end of the pen or by pointing the pen at the element; the method of identification is determined by the display program.

Two special features are available for the 2250: (1) the alphameric keyboard, for message entry and editing, and (2) the programmed function keyboard, for application flexibility. With the typewriter-like alphameric keyboard, the user can enter alphameric messages consisting of letters, numbers, and/or special symbols into the display program for display and editing. The programmed function keyboard provides communication between the user and a CPU program. The keyboard consists of keys, indicators, and sensing switches for use with replaceable descriptive overlays. The function of each key and indicator is defined by the CPU program. Punches in the top edge of each overlay identify the overlay to the CPU program; key and/or indicator labels can be placed on the overlay to identify the key and indicator functions to the operator. Each key can be used by the program to initiate a subroutine associated with the respective overlay, thereby performing the indicated function. For example, depression of a key might result in the enlargement, reduction, or deletion of the displayed image.

The 1130/2250 system is personalized and

compact. Because the 2250 is located close to the 1130, the system can be operated as a single unit. The extended table top on the 2250 provides a convenient workspace for the system user. In addition, the 1131's internal disk drive is easily accessible from the display user position; thus, the user has easy access to removable 2315 disk cartridges, which can be used to retain data and programs relating to his applications.

The logical capabilities of the 2250, combined with the stored program facility provided by the 1130, allow the user great flexibility in designing his "man-machine" interface. The simplicity and versatility of the 1130 and its programming support enable the user to take advantage of this inherent flexibility.

2250-4 DISPLAY SECTION

The 2250-4, under control of the display program in 1130 storage, generates images on the 12-inch by 12-inch usable display area of a 21-inch cathode-ray-tube (CRT). An image can comprise straight lines (vectors), points, and characters.

A visible display is produced when an electron beam in the CRT strikes the phosphor-coated CRT screen, causing the portion of the coating struck by the beam to glow briefly. Normally, the glow fades within a fraction of a second, too soon for the human eye to carefully perceive and identify the image. For this reason, the display must be redrawn continuously (regenerated) at a rate that will cause the display to appear steady and stationary to the observer. Regeneration is performed automatically under control of the display program.

Storage addressing is performed in the 2250 channel interface section (Figure 2). Once regeneration is started by an 1130 I/O control command, the 2250 channel interface section continuously fetches orders and data from the display program in storage. Orders are decoded in this section, and deflection information is transferred to the 2250 display section, where it is used to draw the appropriate display. Regeneration is accomplished by continuously repeating the display program. Orders and data in the display program can be

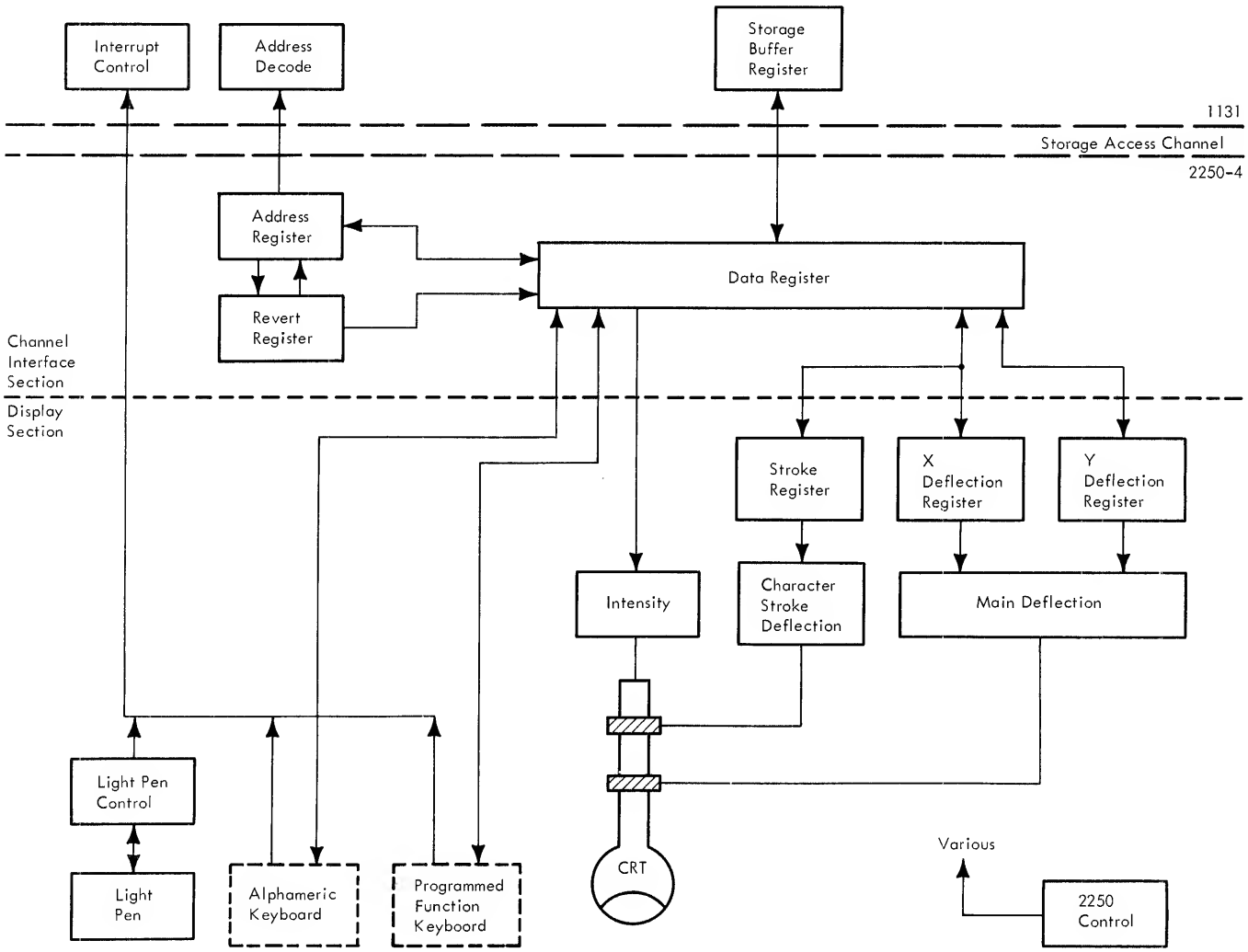


Figure 2. Functional Sections of 2250-4

modified during regeneration, as directed by the CPU program or by the display program itself, to update or change the display.

The 2250 display section also performs various nondisplay services for the user by providing the interface between the user and the problem program with the following devices:

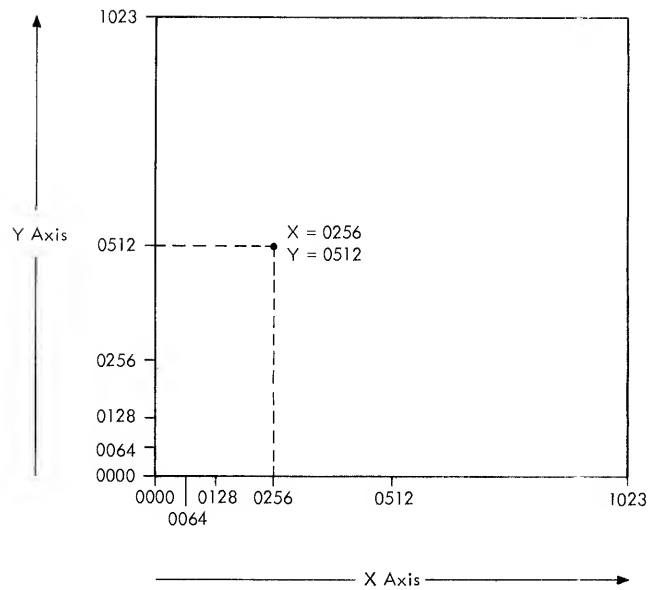
1. Programmed function keyboard. Provides keys and overlays (for user communication to the program) and indicators (for program communication to the user).
2. Alphameric keyboard. Enables the user to change, edit, and/or create character displays. Note that alphameric keyboard key codes can be interpreted by the CPU program and used for control purposes in a manner similar to operations with the programmed function keyboard.
3. Light pen. Provides the means by which the program can identify the storage address of the order that initiated display of a vector, point, or character at which the user is pointing a pen-like device. This information can be used for operations as determined by the display program, by the alphameric keyboard, or by the programmed function keyboard. Thus, the light pen enables the user to enter and manipulate graphic information.

DISPLAYS

Information positioning on the 2250 display area is controlled by a display program in 1130 storage. This program is sent to the 2250, by 16-bit word, via the 1130 storage access channel. Orders in this program specify electron beam deflection to horizontal (X) and vertical (Y) coordinates on a square grid composed of possible electron-beam-deflection end points. This grid, called the "reference grid", covers (logically) the 12-inch by 12-inch display area on the face of the CRT; it comprises 1,024 equally spaced X positions and 1,024 equally spaced Y positions (Figure 3).

Positioning orders in the display program select the X and Y coordinates for each element of a 2250 display (each point, line end point, and character area centroid). The grid of addressable coordinates is called a "raster". The distance between two sequentially addressable lines on the raster is called a "raster unit". Thus, a raster unit represents 1/1,023 of the image (in either the X or the Y direction).

The 2250 can display information in either of two modes: Graphic or Character. Graphic mode is the normal 2250 mode of operation. As such, it is retained through interrupts and Character mode operations, even when it has not been set previously.



Note: One raster unit = 0.0117 inch, 85 raster units = 1.0 inch, and 1023 raster units = 12 inches.

Figure 3. Display Area Coordinate Addressing System

Graphic Mode

Either vector or point operations can be performed by the 2250 in Graphic mode; if no specific Graphic mode has been set previously by an order from the display program, Vector mode is set automatically. In Graphic mode, the 2250 can receive, from the display program, either (1) electron beam positioning orders, or (2) an order to establish a different mode of operation, such as to set Point mode from Vector mode or to enter Character mode from Graphic mode.

When the 2250 is in Graphic mode, positioning orders from the display program directs electron beam movement (deflection) on the reference grid. Positioning orders address the X, Y coordinates to which the electron beam is to be repositioned. Beam deflection is always from the previously addressed coordinates (where the beam is currently positioned) to the new coordinates. If the 2250 is in Vector mode and a vector is to be displayed, the beam is turned on (unblanked) as it is being repositioned, displaying a line between the current position and the new position specified; in point mode, the beam is unblanked after it has been repositioned, displaying a point at the new position. Points plotted 4 or more raster units apart can be distinguished by the viewer as distinct points.

Positioning orders can also reposition the electron beam without causing a visible line or point to appear on the display. This capability is used to select a starting location for displaying charac-

ters or to start the display of a new set of vectors or points. The positioning order for each vector and point contains a beam control bit, which specifies whether the 2250 is to display the associated vector or point or is to reposition the beam without causing a display.

The positioning order for each deflection specifies not only the new beam position and beam condition; it also specifies the format in which the new position is presented. The new position for each deflection can be presented in any of three formats: long absolute, short absolute, or incremental. Operations performed by the 2250 are different for each type of order.

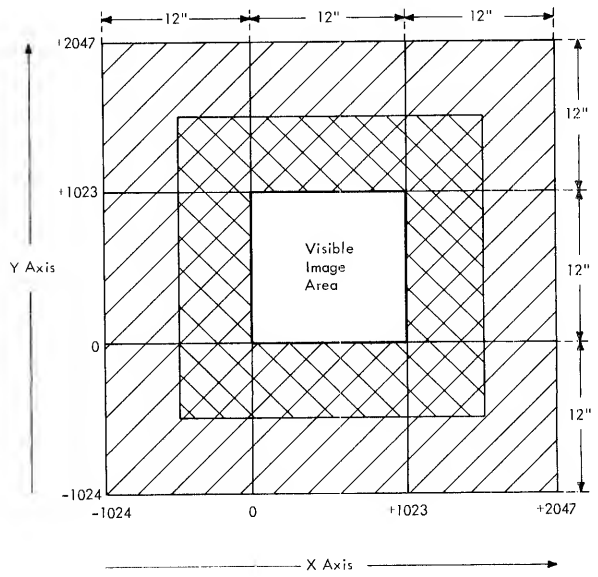
Long-absolute orders specify the actual X, Y coordinates to which the beam is to be deflected. Each pair of long-absolute order words addresses one pair of coordinates on the reference grid (e.g., X = 0512, Y = 1016). Any grid position can be addressed, and a deflection of any length and in any direction can be specified.

Short-absolute orders specify deflection either in the horizontal (X) direction or in the vertical (Y) direction, but not both. Each short-absolute order addresses one X or Y coordinate on the reference grid; the axis not specified in the data remains unchanged. The beam is deflected horizontally or vertically to the addressed coordinate. For example, if the beam is at position X = 0512, Y = 0512, only four short-absolute orders are needed to draw a box; each order might specify a coordinate as follows:

1. Y = 0612
2. X = 0612
3. Y = 0512
4. X = 0512

Incremental positioning orders specify the amount and direction of beam deflection relative to the current beam position. Each incremental order specifies one increment (up to X = +63 or -64, Y = +63 or -64, a displacement of 0.74 inch) of beam deflection. For example, if the current beam position on the reference grid is X = 0512, Y = 1016, and if an incremental order specifies X = +20, Y = -40, beam deflection will be to position X = 0532, Y = 0976 on the reference grid. Thus, the ±X, ±Y incremental value is added to the absolute value of the current beam position, resulting in a new absolute value for the new beam position.

When incremental orders cause the beam to move outside the reference grid area, and when a total displacement of 1,024 raster units beyond the perimeter in the X or Y direction is not exceeded, the vectors and/or points so displaced will be blanked and the X and/or Y overflow bit(s) will be set. In this case the X, Y deflection registers will contain the value of a wraparound position; e.g., when the beam is moved 10 raster units in the +X direction from position X = 1023, Y = N, the wraparound position is X = 10, Y = N, and the X overflow bit is set. Unless the overflow limit of 1,024 raster units is exceeded (Figure 4), the displaced beam can be returned to the normal grid area; then, displaying will resume when a positioning order specifies an unblanked deflection that is entirely within the normal display area.



Note: Using Incremental Graphic orders and/or incrementally positioned characters, any element within the double-crosshatched area can be displayed on the image area without causing wraparound.

Figure 4. Extended Grid for Incremental Deflection Off Display Area

When a portion of a display is blanked because of a beam displacement condition, the display program can return that portion to the visible display area by issuing (1) a long--absolute order, (2) incremental orders in the opposite direction, or (3) one or two short--absolute orders, depending on whether the beam is off in one direction (X or Y) or is off in both directions (X and Y).

Electron beam deflection to the previously addressed coordinate can still be in progress when the next coordinate data is received. When the deflection currently in process is completed, the beam bit is sent to the intensity control section, and the new X, Y coordinates are sent to the main deflection section.

The main deflection section applies X and Y analog values for the current beam position to the deflection coil of the CRT until a new positioning order is received, at which time the analog values start changing to reflect the new position. As the analog values change, the beam moves, causing the

image to be displayed. If the beam bit specifies a blanked deflection, the beam moves without being displayed. If the beam bit specifies an unblanked deflection, the electron beam is moved and unblanked as required to display a vector or point.

The X and Y position registers always contain the absolute X, Y address of the current beam position in digital form; the contents of these registers can be retrieved to reconstruct the most recent positioning data.

Note that long-absolute, short-absolute, and incremental orders can be intermixed since each is uniquely identified and does not require a mode to be set. In addition, any nongraphic order can be intermixed with graphic data without terminating the Graphic mode (point or vector).

Character Mode

The set of characters that can be displayed by the 2250 in Character mode is defined by the programmer. This character set resides in 1130 storage as a subroutine of the display program and can comprise any number of characters in any font; these characters can be modified at any time during execution of the display program. Characters in this set can be displayed in either of two sizes, basic or large, as determined by the character mode order.

In Character mode, the current X, Y position of the beam on the 1,024-by-1,024 position display area becomes the center of a basic-size or large-size character area, which is maintained throughout one Character mode operation. The program normally places the beam at a starting position on the display area (using a blanked point or vector) before a character display operation is started.

The character area is divided into a grid format of 6X-by-7Y addressable points (Figure 5); note that character grid points do not coincide with the 1,024-by-1,024 points on the reference grid. A character is drawn in this area with a series of high-speed deflections, or "strokes". An average of six such strokes is required to form one upper-case character; lower-case characters may require more strokes. Two stroke end points are specified in each word of stroke data from the display program. The character deflection section (Figure 2) converts each stroke end point to X and Y analog signals; these are applied to the high-speed character stroke deflection coil of the CRT.

The main deflection system and the character deflection system operate independently. The main deflection system maintains the current beam position (the center point of the character grid) by supplying a constant X and Y analog current to the

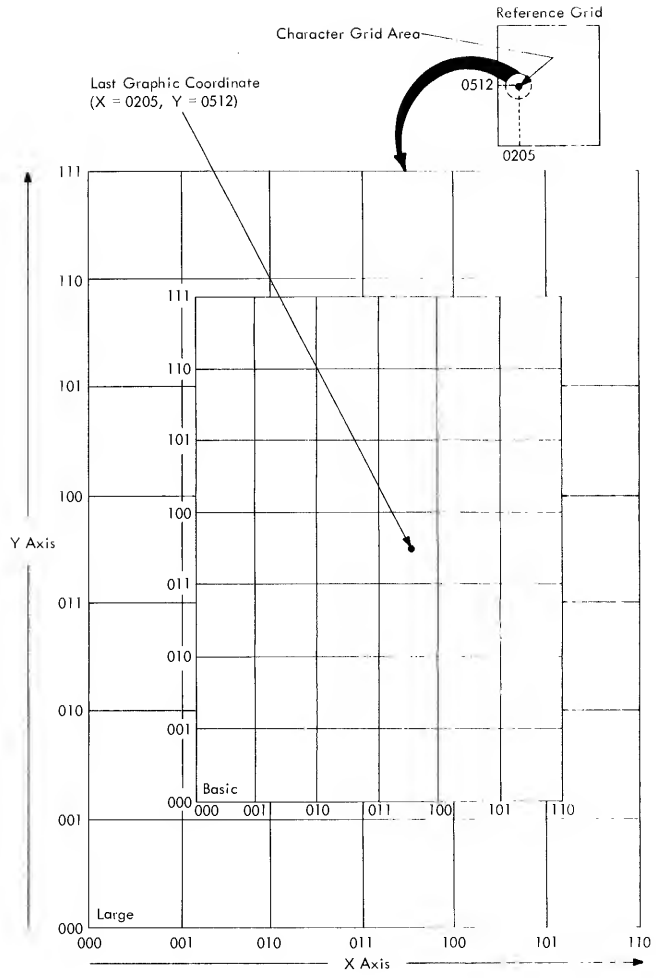
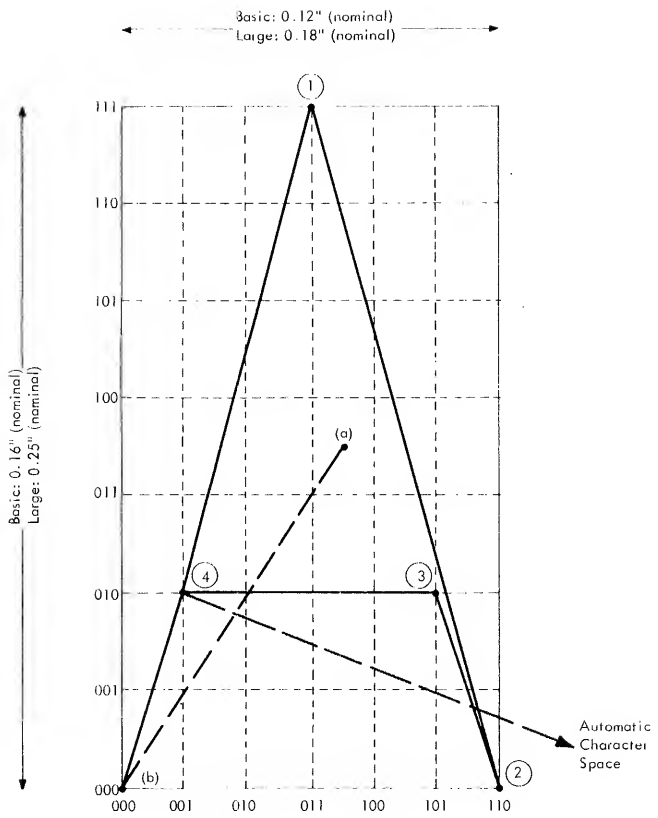


Figure 5. Character Grid Coordinate System

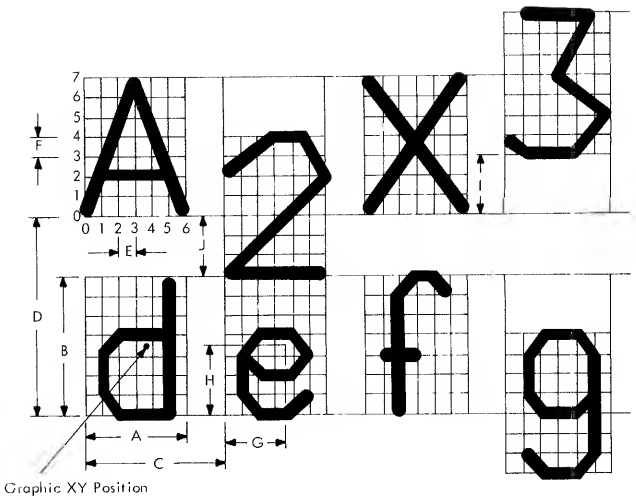
main deflection yoke. At the same time, the character deflection system offsets the beam to position X = 000, Y = 000 of the character grid upon entering Character mode and then forms a character by moving the beam at high speed between various addressed points in the character grid area. Figure 6 illustrates the strokes used to form the character "A".

Figure 7 shows the characteristics of a character display. Character spacing is an automatic function of the 2250. A special bit, called the "revert" bit, is set in the last data word for each character. (The revert bit is used during other operations, as described later in this document.) This bit causes the main deflection system to move the electron beam in the +X direction to the new character area center point. The beam is moved a distance of 14 raster units when displaying basic-size characters or 21 raster units when displaying large-size characters. The program can initiate additional spaces of 14 or 21 raster units



Notes: 1. Circled numbers refer to the sequence in which the deflection end points are addressed.
2. Deflection ob occurs automatically upon entering Character mode. Deflection ba occurs when leaving Character mode, in grid position following last character in string.

Figure 6. Strokes That Form the Letter "A"



Legend	Characteristics	Character Size	
		Basic	Large
	Characters per Line (Max.)	74	49
	Lines per Display (Max.)	52	35
	Number of characters on display (max)*	3,848	1,715
	Character Grid:		
A	Width	10 RU	15 RU
B	Height	14 RU	21 RU
C	Character Spacing	14 RU	21 RU
D	Line Spacing	20 RU	30 RU
E	Horizontal Character Unit	1.7 RU	2.5 RU
F	Vertical Character Unit	2.0 RU	3.0 RU
G	X Offset	6.0 RU	9.0 RU
H	Y Offset	7.0 RU	10.5 RU
I and J	Superscript and Subscript Offset	6 RU	9 RU

* Not flicker-free display

Figure 7. Character Display Characteristics

each by sending the 2250 one two-stroke character word for each space; this word would specify two blanked strokes and should have the revert bit set. Hence, one space character would result in a distance of 28 or 42 raster units between the center point of the previously specified character area and the center point of the next area.

In addition to stroke words, the program can also send control words to the 2250 during Character mode operations. A control word specifies any one of five functions: new line, null, subscript, superscript, or no-operation. These functions are described in the following paragraphs.

Initial character positioning can be accomplished by an absolute or incremental Graphic mode order. For establishing a method of line spacing, characters that follow a long-absolute order are considered to be "absolutely positioned," and characters that follow an incremental order are "incrementally positioned." Intervening short-absolute orders, though executed, do not establish a method of line spacing; instead, the most recent long-absolute or incremental order is the determining factor.

Line spacing is initiated either by the display program or by the 2250. A new line (NL) control word from the display program causes the 2250 to reset the X deflection register to zero and to decrement the Y deflection register by 20 or 30 raster units as determined by character size. Successive NL control words cause successive lines to be stepped. If the Y deflection register underflows (decrements below Y = 0000), and if the characters were absolutely positioned, wraparound occurs so that the new line is positioned at the top of the display area. If underflow occurs during the display of incrementally positioned characters, subsequent lines are positioned below the image area (Figure 4). In addition, subsequent characters are blanked until the beam is returned to the image area, either by a second Y deflection register

underflow (decremented to below Y = 1024) or by one or more Graphic mode orders.

Automatic line spacing is performed during display of absolutely positioned characters whenever a character space operation causes the X deflection register to overflow (to increment above X = +1023). If an NL control word is not received, the 2250 (1) displays characters to the end of a line, (2) automatically resets the X deflection register to zero, (3) decrements the Y deflection register by 20 or 30 raster units, depending on character size, and (4) continues the display of characters.

Automatic line spacing is not performed when incrementally positioned characters are displayed. In this case, the X deflection register is not reset if overflow occurs during character spacing. Thus, blanked characters are positioned to the right of the display area, in the same line. If the X deflection register overflows a second time (increments beyond X = 2047), wraparound occurs; the line of characters reappears at the left side of the visible image area. Note that the Y deflection register is not decremented; thus, line spacing does not occur. When outside the image area, in the X direction, the beam can be returned (1) by an NL control word, (2) by Graphic orders, or (3) by the second X deflection register overflow.

The null control word does not cause a display, does not affect the X, Y position registers, and does not cause character spacing. It can be used as the last word of a character to permit superimposed characters and can be used in character strings to reserve storage space for characters added by the operator.

The subscript control word causes the character grid to be offset downward from its normal position by three vertical character units (Figure 7). The grid remains in this offset position (1) until a character space is performed (initiated by receipt of a stroke word with the revert bit set), (2) until a superscript control function is executed, and (3) until a null control function is executed. The subscript function enables the drawing of subscripts, of lower-case letters that extend below the line, or of strokes (such as underlines) beneath normally positioned characters.

The superscript control word causes the character grid to be offset upward from its normal position by three character units (Figure 7). The grid remains offset until a revert-initiated character space if performed or until subscript or null control function is executed. The superscript function enables the drawing of superscripts and of strokes above normally positioned characters.

Control words that contain undefined codes are no-op'ed. However, a revert bit in these words, if set, causes execution of the revert function. Thus, no-op's can be used to reserve CPU storage locations for later use by a program.

LIGHT PEN

The light pen, a fiber-optic device (Figure 8), provides two independent inputs to the 2250; light-pen detect status and light-pen switch status. First, the user points the light pen at the section of displayed image he wants to identify to the display program or the CPU program. A light-pen detect can occur whenever light from the CRT beam passes within the light pen field of view. In addition, when the light pen is in the desired position, the user can press the pen tip against the CRT faceplate to activate the tip-switch.

Activation of the light-pen switch and the occurrence of a light-pen detect are independent functions, and their significance is determined by the display program. The display program can disable (or ignore) light-pen detects and ignore switch closures, or it can establish that any one of the following conditions is significant:

1. Light-pen switch closed (detect or no detect).
2. Light-pen detect (switch open or closed).
3. Light pen detect and light pen switch closed.

Following the occurrence of the significant condition(s), the program can interrupt the CPU or can branch operations to a new storage address.

When light-pen detects are enabled (or made significant) by the program, a detect occurs each time the unblanked beam passes within the light pen field of view. This "continuous detects" mode can be used in graphic design operations such as light pen tracking. In addition, the display program can ignore the light pen while certain information (such as a background grid) is being displayed, inhibiting light-pen-initiated operations on that information.

Two small beams of light projected by the light pen appear as two small dots on the CRT faceplate. These dots assist the user in aiming the light pen by "bracketing" the image section that is within the light pen field of view.

ALPHAMERIC KEYBOARD

This special feature provides a typewriter-like keyboard with which the user can compose and/or modify messages (on the CRT display area) not protected by the CPU program from keyboard action. Identification (to the user) of the character or character position that can be modified or inserted by the keyboard is a program function.

The keyboard (Figure 9) has 44 character keys and a SHIFT key, which provide a selection of 90 EBCDIC characters (Figure 13). Each alphabetic

Figure 8. Fiber Optic Light Pen

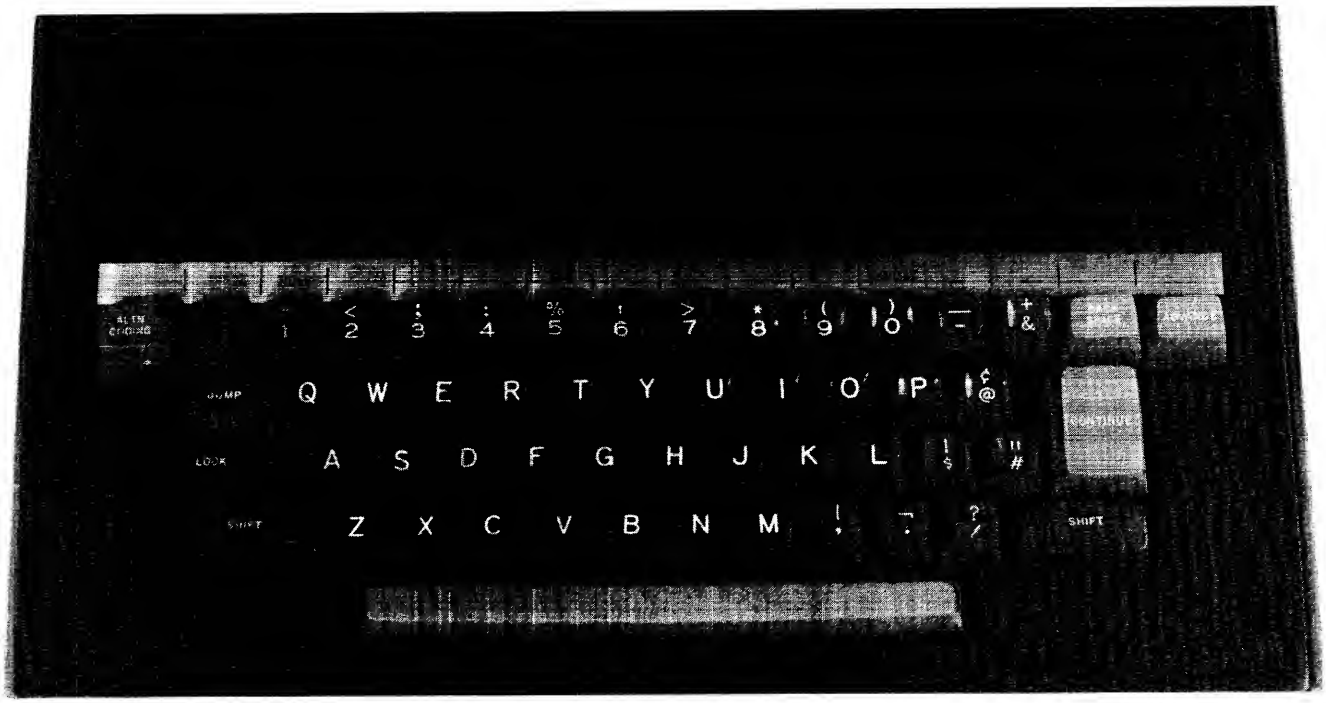


Figure 9. Alphameric Keyboard

key can provide the upper- or lower-case character as selected by the user. In addition to standard character keys, the following function keys are provided:

SHIFT: When depressed, allows selection of any upper-case alphabetic character or any of the upper characters identified on the dual-character keys. When released, any lower-case alphabetic character or lower dual-character-key character can be selected.

LOCK: Holds SHIFT key in the down position.

ALTN CODING: Allows selection of NULL, END, or CANCEL; when pressed with any other key, generates a null code.

CONTINUE: When held down with a character or control key, the character or control key code is entered once per regeneration cycle until the CONTINUE key is released.

END, CANCEL, ADVANCE, BACKSPACE, and JUMP: The functions of these keys are established by the CPU program. Each key sets a unique bit which can be retrieved by the program.

Each time a key other than SHIFT, LOCK, ALTN CODING, or CONTINUE is depressed, the keyboard locks, regeneration is terminated at completion of the current cycle, and an interrupt is requested. The CPU program can respond to this request by issuing commands to read the key code and to unlock the keyboard.

PROGRAMMED FUNCTION KEYBOARD

The programmed function keyboard (Figure 10) contains 32 keys, 32 indicators, and eight switches which sense a code punched into the top edge of an overlay (Figure 12). The application program defines the function of each key and indicator. Each of 256 possible coded overlays identifies the function of the keys and indicators, both to the operator and to the CPU program; key and/or indicator labels can be placed on the overlays. Each key can be used by the program to initiate a subroutine associated with the respective overlay. When a key is pressed, the keyboard is electrically locked (keys can be pressed, but they have no effect), regeneration is stopped, and a CPU interrupt is requested. The CPU program can respond to this interrupt by issuing an I/O Control command (IOCC) to read the key and overlay codes. Then, the CPU program can perform the indicated function and restart the display, thereby unlocking the keyboard. For example, depression of a key might result in the enlargement, reduction, or deletion of a displayed image.

Plastic overlays (PN 5704496) are available directly from the DP Administration Operations Office (AOO). One overlay punch (PN 5704549) per installation is furnished to each customer at no charge. Additional punches can be ordered on an

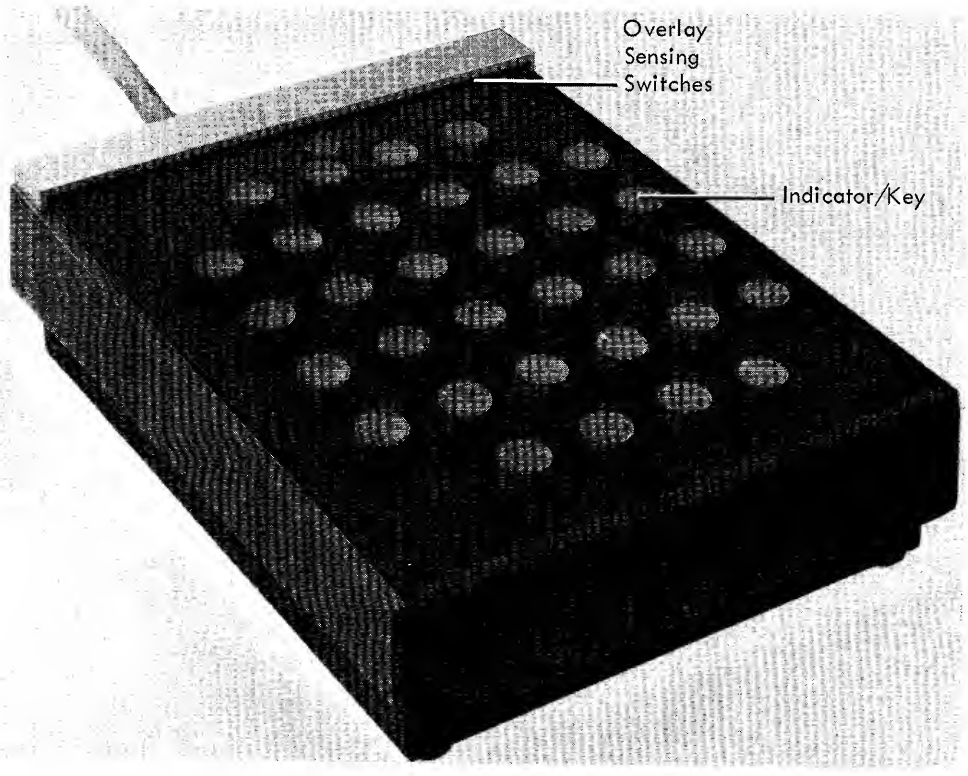


Figure 10. Programmed Function Keyboard

MES from IBM Kingston.

Each of the 32 programmed function keyboard keys has a built-in indicator. Operation of these indicators is independent of the operation of the keys; however, the indicators can be used for associated functions such as informing the operator of the keys that can be, or have been, activated.

2250 OPERATOR CONTROL

The 2250 is equipped with a BRIGHTNESS control with which the operator can adjust the light intensity of the overall display for a given regeneration rate. Improper adjustment of this control might result in faulty light pen operation.

METERING

The 2250 is metered as an assignable unit on the 1130. It contains a usage meter to record customer run time and an Enable/Disable switch. The 2250 records time when all of the following conditions are met:

1. Power is on (controlled at 1131).
2. The 2250 is in the enabled state.
3. The CPU or cycle-steal I/O devices are running (not in CE mode). (Cycle-steal I/O devices include disks, 2501, 1403, 1132, and 2250.)

The Enable/Disable switch allows the 2250 to become logically enabled or disabled. When the 2250 is logically disabled, the usage meter is prevented from recording time and the 2250 is prevented from operating; it is logically disconnected (off-line) from the 1130, and signals are not transmitted across the interface. When the 2250 is enabled, it is on-line, and the usage meter records time.

The Enable/Disable switch setting may be changed at any time. However, the 2250 state does not change until the following conditions occur simultaneously for a minimum period of 1usec: (1) the CPU is in the Wait state or in CE mode, and (2) all I/O operations (including those of the 2250) are stopped. Note that the usage meter does not record time when the 1130 is in CE mode or when the CPU and cycle-steal I/O devices are not running.

2250-4 CHANNEL INTERFACE SECTION

GENERAL

The 2250-4 channel interface section (Figure 2) interfaces the storage access channel and the 2250-4 display section. It decodes and executes orders and commands, addresses CPU storage, and handles data transferred to or from CPU storage. Information transfer across the storage access channel/2250 interface is by 16-bit word.

An address register in the 2250 channel section specifies, to CPU storage, the location at which information will be stored or from which it will be retrieved for 2250 operations. This address register is loaded initially by an Initiate Write (Start Regeneration) command from the CPU program; it can then be stepped automatically by the 2250, altered by the display program, or reloaded by the CPU program. Thus, display regeneration can be performed without CPU intervention.

The display program consists of display orders, associated data for image generation, and control orders for various nondisplay functions. Table 1 lists the 2250 order set. Undefined order codes received by the 2250 are treated as no-operation orders or are interpreted as data if in the appropriate format.

The CPU program initiates 2250 operations by issuing an Execute I/O (XIO) instruction. The I/O Control command (IOCC) at the effective storage address specified by XIO is then sent to the 2250. If the IOCC is Initiate Write (Start Regeneration), the 2250 fetches display program information from main storage, starting at the IOCC-specified address.

Table 1. 2250-4 Order Set

Type	Name	Variation(s)	Mnemonic	Comments
Display Orders	Set Graphic Mode	Vector	SGMV	
		Point	SGMP	
	Long Absolute XY	Absolute XY	DBA	Beam on
		Absolute XY	MBA	Beam off
	Short Absolute XY	Absolute X	DBAX	Beam on, X deflection
		Absolute X	MBAX	Beam off, X deflection
		Absolute Y	DBAY	Beam on, Y deflection
		Absolute Y	MBAY	Beam off, Y deflection
	Incremental XY	Incremental XY	DBI	Beam on
		Incremental XY	MBI	Beam off
	Set Character Mode	Basic	SCMB	
		Large	SCML	
Data Words	Character Stroke Word (2-stroke mnemonics generate one stroke word)	Stroke	DBS	Beam on
		Stroke	MBS	Beam off
		Control Word	CS	Control code

Type	Name	Variation(s)	Mnemonic	Comments
Control Orders	Short Branch		GSB	One Word
	Long Branch/ Interrupt	Unconditional Branch	GB	All variations are two words, and can be coded as 2-word no-op. Long Branches can be direct or indirect.
		Unconditional Branch, External	GBE	
		Conditional Branch,	GBC	
		Conditional Branch, External	GBCE	
		Unconditional Interrupt	GI	
		Conditional Interrupt	GIC	
	Set Pen Mode	Set Pen Mode	SPM	Several options selected by modifiers.
		Graphic No-Operation	GNOP	
	Start Timer		STMR	
	Revert		RVT	
	Store Revert Register		SRVT	

NOTE: The mnemonics shown are those used by the IBM 1130 Disk Monitor Assembler.

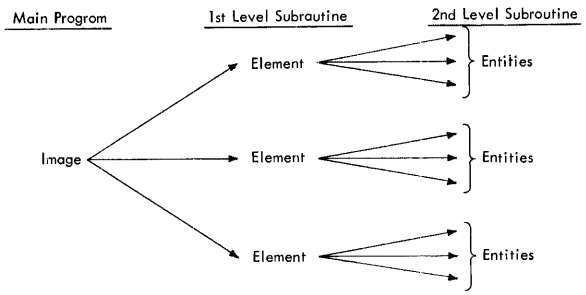
Display program information consists of orders and data. Orders either initiate a 2250 operation or establish a mode. Order-initiated operations include point and vector plotting, branching, and CPU interrupt generation. Two orders, Set Graphic Mode and Set Pen Mode, establish a Graphic mode and a Light Pen mode respectively. The 2250 is always in one of two Graphic modes and in one of four Light Pen modes.

Data is defined as information that does not contain an operation code. Character stroke words are the only data received by the 2250. Although a character stroke word may contain one or more control bits, these bits are used directly to perform an operation.

SUBROUTINES

Single-level subroutines (linkage from the main order program to the order subroutine and return to the main order program) are used frequently in graphic application. Thus, facilities for a rapid (unconditional) branch to a subroutine and return from the subroutine are provided. Since characters are similar to single-level subroutines, rapid branching significantly reduces character display time.

Orders in the display program enable multiple-level subroutine linkages to be performed. A single-level subroutine facility does not allow characters to be displayed as part of a subroutine, nor does it permit the organization of an image in a hierarchy of graphic segments represented by multiple-level subroutines, as follows:



Notes: 1. Examples of elements are elevation, plan, and end-views of a part.
2. Examples of entities are bolt heads, brackets, and supports.

Each graphic sub-picture (element) and each entity can be represented as a subroutine. This is useful in representing display images and performing manipulations on them. The multiple-level subroutine linkage is accomplished by:

1. Storing the return address (i.e., the address of the order following a branch order) in a particular core storage location.
2. Branching indirectly to the location of the return address; thus, the ultimate branch would be the next-higher subroutine level.

Graphic Subroutines

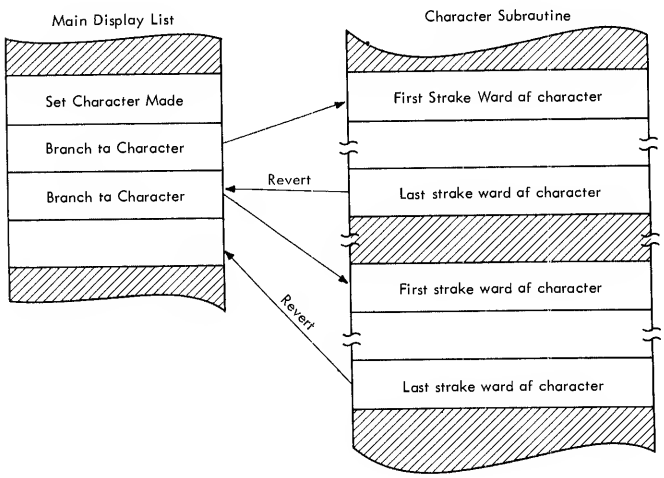
A graphic subroutine is a sequence of display orders which forms a logical element of entity. This method of graphic data organization substantially improves the efficiency of the CPU in the generation of graphic data. For example, the generation program can insert a vector to position the beam and then can provide a linkage to a subroutine representing a logic block in a logic diagram.

Using incremental vectors, the subroutine can generate a display of the logic block about the original reference point; then, linkage can be made back to the main sequence of display orders. The alternative is to require the CPU to place a copy of the logic block orders in the main graphic order sequence every time it appears in the displayed image. Consequently, the graphic subroutine capability substantially reduces storage requirements in instances where an image entity appears repetitively in a display.

In applications where the display images comprise groups of elements (e.g., resistors, capacitors, logic blocks, etc.), graphic subroutines, together with the "defer light pen interrupt" light-pen control order, allow the correlation of a light-pen detect with a group of elements. In many cases, identification of the group is required, rather than the particular element in the group which was detected.

Character Generation

Character generation is a programmable function, allowing the user complete flexibility in the generation and use of character sets. Characters represented by their component strokes are stored in 1130 storage. Up to two character strokes are contained within the 16-bit 1130 word. The character stroke words are organized so that each character can be represented by a subroutine of stroke words. Characters, then, can be drawn by the following general sequence of display orders:



The first branch order transfers program execution to the character stroke words representing the character. The last character stroke word of the character contains the revert bit, which, when decoded, causes an automatic branch back to the main display list. In addition, the beam automatically steps in the +X direction to the next character position. Control codes within the character stroke word are used (1) to suppress spacing, (2) to position the beam to a new line, (3) to position the beam to a point above or below a line to allow certain lower-case letters (such as y and p) to be drawn, and (4) to reserve a location in CPU storage for later use by a program.

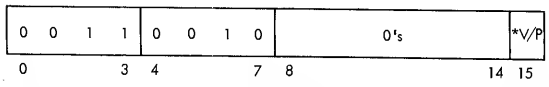
If, after branching back from a character subroutine, the next order in the main display list is not a branch order, Graphic mode is re-entered automatically. If a specific Graphic mode (Vector or Point) has been set previously, that mode remains set. Otherwise, Graphic mode (vector) is set automatically. If a branch/interrupt to a noncharacter subroutine is needed immediately after a series of branches to character subroutines, a nonbranch type of order such as Set Pen Mode is inserted after the last branch to the character subroutine. This order causes Character mode to be left and Graphic mode to be re-entered automatically.

DISPLAY ORDERS

Display orders set point mode, return the 2250 to vector mode, or direct the 2250 to position and blank or unblank the electron beam. Display mode operations by the 2250 are described in the preceding section of this publication. In summary, the Set Graphic Mode order specifies the display of vectors or of points under direction of graphic orders from the display program. These orders can be in long absolute, short absolute, and/or incremental format (these formats can be intermixed). The set Character Mode order specifies either basic or large character size; stroke data from a stroke table in the display program directs electron beam movement to form characters.

Programming Note: For improved image accuracy on complete images that are displayed in less than 25ms, the beam should be returned to the center of the display area (X = 512, Y = 512) after the image is displayed.

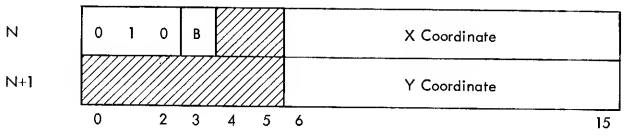
Set Graphic Mode (Vector/Point) (SGMV, SGMP)



Note: Bit 15 = 0 for vector operations (SGMV), or = 1 for point operations (SGMP)

This order prepares the 2250 to operate with Long Absolute, Short Absolute, and Incremental orders, which can be intermixed. Graphic mode is entered automatically following execution of any order other than a branch that is in a character sequence. The 2250 is placed in the Graphic mode established by the most recent Set Graphic Mode order. If a mode was not established previously, the 2250 is placed in Graphic (Vector) mode.

Long Absolute XY (MBA, DBA)

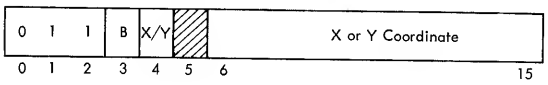


Note: Beam (B) bit = 1 for beam on (DBA), or = 0 for beam off (MBA)

Each Long Absolute XY order identifies one beam deflection end point. Bits 0-2 in the first word identify the order as Long Absolute XY. Bits 6-15 in each word address the actual reference grid coordinates to which the electron beam is to move. A deflection of any length and in any direction can be specified.

A vector or point, as determined by the current 2250 Graphic mode, is displayed if the beam bit is 1, or the beam is repositioned without causing a display if the beam bit is 0.

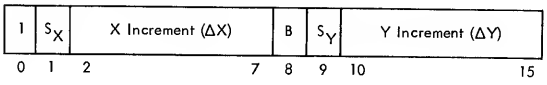
Short Absolute X/Y (MBAX, MBAY, DBAX, DBAY)



Notes: 1. Beam (B) bit = 1 for beam on (DBAX or DBAY), or = 0 for beam off (MBAX or MBAY)
2. X/Y bit = 0 if an X coordinate is in bits 6-15, or = 1 if a Y coordinate is in bits 6-15.

Each one-word Short Absolute X/Y order causes beam deflection either in the horizontal direction or in the vertical direction, whichever is specified by bit 4. Bits 6-15 address the actual X or Y reference grid position to which the electron beam is to be deflected. This order can be used to display a horizontal or vertical line or to display a point, as determined by the current 2250 Graphic mode. It can also be used for electron beam positioning without causing a display, as determined by the beam bit.

Incremental XY (MBI, DBI)



Notes: 1. Beam (B) bit = 1 for beam on (DBI), or = 0 for beam off (MBI).
2. Sign (S_X or S_Y) = 1 when associated increment is negative, or = 0 if the increment is positive.

Incremental graphic orders provide the capability of displaying a graphic image by specifying incremental displacement from an absolute beam position. A maximum displacement of +63 or -64 raster units can be specified for X and for Y. Each displacement value can be positive or negative; when negative, the data is presented in 2's complement form. The incremental X and Y values are added to the absolute X and Y values (the current beam position), providing a new absolute value for a new beam position. Figure 11 is a chart that shows conversion from decimal raster units to hexadecimal coding.

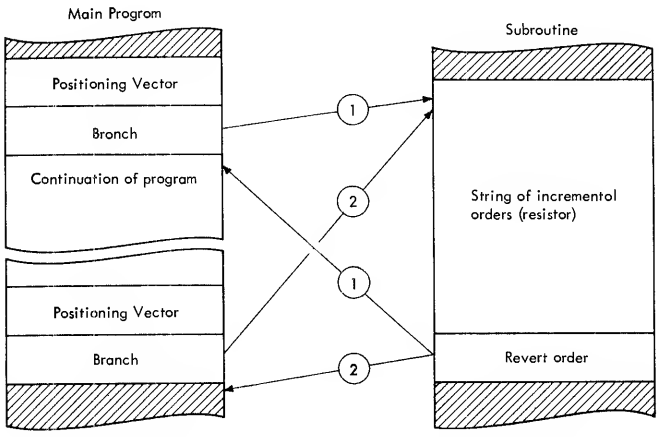
The S_X and S_Y bits in each incremental order word are the signs of the X and Y increments, respectively. A 0 sign bit signifies a positive increment, whereas a 1 sign bit signifies a negative increment in 2's complement form. The beam bit is a 1 if a point or vector is to be displayed, or it is a 0 if the beam is to be repositioned without causing a display.

Each incremental deflection starts at the current beam position and ends at an X, Y position determined by the 2250 as follows:

X new = X current ± X,

Y new = Y current ± Y,

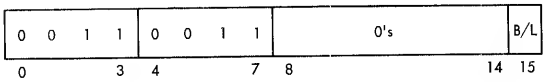
Note that a string of incremental vectors or points can be moved about the screen without affecting their length or orientation by changing the absolute starting position of the string. For example, a string of incremental orders to form a resistor could be in a subroutine; this string could be used to display the resistor any number of times, anywhere on the screen, as determined by the main program:



Incremental orders and absolute orders can be intermixed because all are uniquely identified, and a mode need not be set for their operation. Any nongraphic orders can also be inserted between graphic orders without terminating the Graphic mode, as can commands and interrupts.

If an X or Y increment causes the beam to move outisde the 1,024 raster-unit image area, the point or entire vector will be blanked, as will all subsequent increments until the beam is returned to the usable image area; both end points of a vector must be on the image area for the vector to be displayed. The beam can be returned in either of two ways: by incremental movement in the opposite direction, or by an absolute positioning operation. If it is returned by an unblanked Long Absolute Vector order, the beam will be moved (blanked) from a wrap-around position to the end point specified in the vector data. Note that if beam displacement outside the image area exceeds +2047 or -1024 (X or Y), the beam may wrap around (may reappear on the opposite side of the usable display area). A Short Absolute X/Y order will return the beam to the image only if it is off-screen in the direction selected by X/Y bit.

Set Character Mode (Basic/Large) (SCMB, SCML)



Note: Bit 15 = 0 for bosic - size chorocters (SCMB), or = 1 for lorge size charocters (SCML)

This order places the 2250 in Character mode and specifies that large- or basic-size characters are to be drawn (Figure 7). The set of characters that can be displayed by the 2250 is defined by the programmer. This character set resides in CPU storage as a stroke table or list in the display program. It can comprise any number of characters in any font and can be modified at any time during execution of the display program.

When entering Character mode, the current beam position on the reference grid becomes the center of a character area. (Normally, the program uses a blanked point or vector to establish a starting position before entering Character mode.) This character area is divided into a logical grid of seven X by eight Y addressable positions (Figure 5). A character is drawn in this area with a series of high-speed strokes between addressable positions, as specified by stroke data from the display program. In addition, character control data can be interleaved with stroke data to specify a subscript, superscript, new line, or null function.

Upon entering Character mode, the beam is offset automatically to position X = 0, Y = 0 in the first character area and is spaced automatically to this position in subsequent character areas. The beam is reset to the center of the character area upon leaving Character mode.

In Character mode, only Short Branch and Long Branch/Interrupt orders can be executed without

1st Char./ 3rd Char. (Beam on)	3rd Char. (Beam off)	2nd/4th Hex Character of Order															
		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
8	0	+0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14	+15
9	1	+16	+17	+18	+19	+20	+21	+22	+23	+24	+25	+26	+27	+28	+29	+30	+31
A	2	+32	+33	+34	+35	+36	+37	+38	+39	+40	+41	+42	+43	+44	+45	+46	+47
B	3	+48	+49	+50	+51	+52	+53	+54	+55	+56	+57	+58	+59	+60	+61	+62	+63
C	4	-64	-63	-62	-61	-60	-59	-58	-57	-56	-55	-54	-53	-52	-51	-50	-49
D	5	-48	-47	-46	-45	-44	-43	-42	-41	-40	-39	-38	-37	-36	-35	-34	-33
E	6	-32	-31	-30	-29	-28	-27	-26	-25	-24	-23	-22	-21	-20	-19	-18	-17
F	7	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1

Number of Raster Units

Examples:

ΔX	ΔY	Order Code (Hex)	
		Beam on	Beam off
-23	+27	E99B	E91B
+62	+6	BE86	BE06
-36	-51	DCCD	DC4D
+63	-64	BFC0	BF40

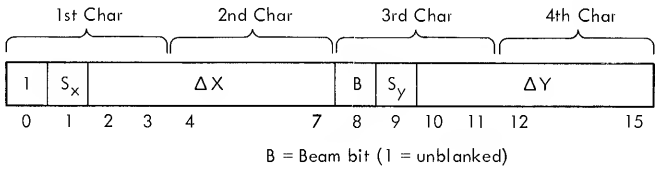


Figure 11. Decimal-Hexadecimal Conversion Chart for Incremental Orders

causing the 2250 to leave Character mode. (For maximum efficiency in generating characters, Short Branch orders should be used because their execution is overlapped with character spacing operations.) The Set Character Mode order should be followed by a branch order pointing to the character subroutine for the first character to be generated. Then, the strokes to form this character are drawn sequentially until a stroke word having the revert bit set is received by the 2250; after both strokes in this word are drawn, control is reverted to the main program location following the branch. If this location also contains a branch order, character generation continues as above. Character mode is terminated when a nonbranch order is decoded in the main order program, allowing the previously selected Graphic mode (vector or point) to continue.

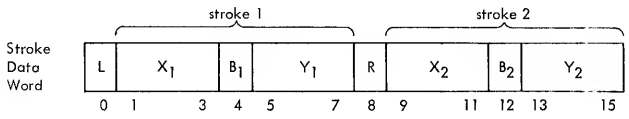
All words in a stroke table are treated as stroke or control data; orders in a stroke table are not decoded. Branches to null strokes can be used to reserve locations in the character string without spacing. If the light pen detects a stroke, the detect status bit is not set (and an interrupt is not requested) until the revert function and spacing are completed.

Programming Notes:

1. A Set Character Mode (basic or large) order establishes Character mode until Character mode is terminated with a nonbranch/noninterrupt order.
2. If Character mode is not terminated with a nonbranch/noninterrupt order, the order at the branch destination address order will be treated as stroke data.

Stroke Data (MBS, DBS)

Each stroke data word contains two stroke endpoint addresses, a beam (B) bit for each stroke, a length (L) bit, and a revert (R) bit:



The first stroke addressed by this word is drawn from the current beam position on the character grid to the X_1, Y_1 position; it is intensified if $B_1 = 1$ (DBS). The second stroke is drawn from X_1, Y_1 to X_2, Y_2 and is intensified if $B_2 = 1$. Points can be displayed by positioning the beam with a blanked stroke (MBS) and then addressing one or more unblanked strokes to the current beam position, thereby causing the beam intensification without deflection.

Bit 0 (the L bit) is used to regulate stroke intensity and should be a 1 if either stroke in the

data word is greater than two character units long. Programmed intensity enables the generation of characters that have nearly uniform intensity for all strokes, regardless of the stroke lengths. Visual inspection of a character for uniform intensity might be necessary to verify the setting of a length bit. The user should experiment with this control to achieve optimum results.

Bit 8, the revert bit, is set to identify the last data word of a character. After the two strokes in this last word are drawn, control of the 2250 reverts from the character stroke table back to the main program. Also, the beam is stepped 14 or 21 raster units in the +X direction to position X = 0, Y = 0 of the next character area. Note that a one-word character that specifies two blanked strokes with the revert bit set could be used as a space character to obtain additional space (in multiples of 14 or 21 raster units) between characters.

As an example of how stroke data can be used to form a character, consider the letter "A" shown in Figure 6. This letter could be drawn from two data words, as follows:

	L	X_1			B_1	Y_1			R	X_2			B_2	Y_2		
First Word	1	0	1	1	1	1	1	1	0	1	1	0	1	0	0	0
Second (last) Word	1	1	0	1	0	0	1	0	1	0	0	1	1	0	1	0
	0	1		3	4	5		7	8	9		11	12	13		15

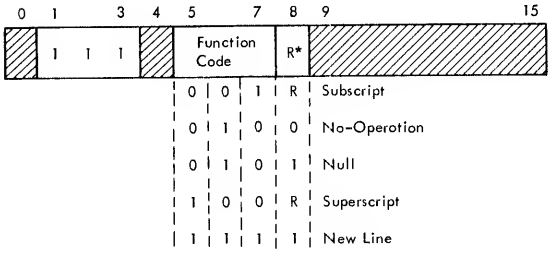
Either the display program or the 2250 can initiate line spacing. Program-initiated line spacing is described under Character Control Words following this discussion. The 2250 initiates line spacing automatically only if the characters were initially positioned by a Long Absolute Graphic (Point or Vector) order (were absolutely positioned). When the X deflection register overflows (increments past 1023), it is reset to 0, and the Y deflection register is decremented 20 or 30 raster units to a new line.

If the characters were incrementally positioned, line spacing is not performed when the X deflection register overflows. The line continues to the right of the image area, and all characters are blanked until the X deflection register overflows a second time (increments past X = 2047), at which time wraparound occurs; then, characters are again displayed in the same line on the image area, starting at the left side. Thus, positioning operations for incrementally positioned characters and for incremental graphics are similar. This feature enables any displayed element to be moved anywhere on the image area without causing wrap-around. Thus, operations can be with a 24-by-24-inch image, of which any 12-by-12-inch square is visible at any one time (see Figure 4).

Programming Note: The most recent Long Absolute or Incremental order determines whether the characters are absolutely positioned or are incrementally positioned. Intervening Short Absolute orders, though executed, are not used for this determination.

Character Control Words (CS)

Any one of five functions can be specified in a character control word: subscript, no-operation, superscript, new line, or null. Coding of the control word is as follows:



*Revert

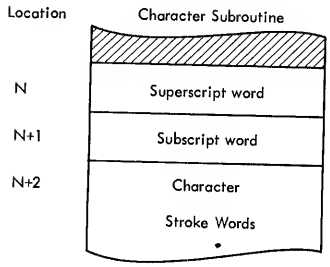
Undefined function codes are treated as no-op's; the revert bit is honored in words with undefined codes. Control words are identified by 1's in bits 1-3.

Subscript. This code causes the character grid to be offset downward from the normal position by three character units (Figure 7). The grid is returned to its normal position following execution of a null control function or of a stroke word with the revert bit set; a superscript control function will move the grid to the superscript position.

Null. This code causes the revert function to be executed; however, character spacing is suppressed. It can be used to reserve locations in the character string without adding character spaces and to superimpose characters when used as the last stroke word of a character.

Superscript. This code causes the character grid to be offset upward from the normal position by three character units (Figure 7) and causes the next location in the stroke table to be skipped. This skip function enables formation of a superscript, subscript, or normal character from one set of

character data. Word arrangement in storage would be as follows:



A superscript is drawn from the stroke data when the main program branches to location N; in this case, location N+1 is skipped. A subscript character is drawn when the branch is to location N+1, and a normal character is drawn when the branch is to location N+2. The grid is returned from the superscript position to its normal position following execution of a null function or of a stroke word with the revert bit set; a subscript function will move the grid to the subscript position.

New Line. This code effects a "carriage return" function by resetting the X deflection register to zero and decrementing the Y deflection register by 20 or 30, according to character size. If the Y deflection register underflows, and if the characters were absolutely positioned, the new line is at the X wraparound position. If the Y deflection register underflows, and if the characters were incrementally positioned, the new line falls below the reference grid area (see Figure 4); in this case, subsequent characters will be blanked until returned to the reference grid area by Graphic orders or by a second underflow.

No-Operation. Reserves locations in the stroke subroutine for later use by the program.

CONTROL ORDERS

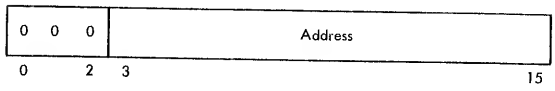
Control orders are provided for (1) conditional and unconditional branching, (2) conditional and unconditional interrupting of the CPU, (3) light pen control, (4) regeneration rate control, and (5) subroutine linkage.

Branch and Interrupt Orders

A branch order is normally the last order in the main routine of a display program. This order accomplishes display regeneration by branching to the first order in the main routine, resulting in repeated operation of the display program. Branch orders are also used in Character mode to reference the character stroke table.

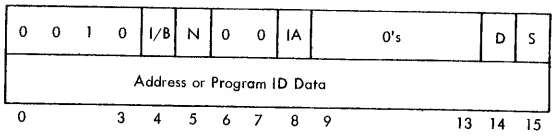
Branch orders enable regeneration, logical decision making, character generation, and order subroutining. There are two branch orders: Short Branch and Long Branch/Interrupt. Short Branch is used for unconditional branching within the first 8,192 words of storage, whereas Long Branch/Interrupt is used for conditional or unconditional branching to any location in storage, for interrupting the CPU, and for no-operations (no-op's).

Short Branch (GBS)



This order causes an unconditional branch to any location within the first 8,192-word block of CPU storage. As it is executed, a full 16-bit return address (address of the location that follows the Short Branch order location in storage) is saved in the revert register. A Store Revert Register order can be used to store the return address in the display program. Either a Revert order, or a character stroke or control word with the revert bit set, will branch operations back to the address specified by the revert register.

Long Branch/Interrupt (GB, GBE, GBC, GBCE, GI, GIC)



NOTES:

1. I/B bit = 0 for interrupt, or 1 for branch
2. N bit = 1 for 2-word no-op
3. IA bit = 1 for indirect addressing, or 0 for direct addressing
4. D bit = 1 for light pen detect condition
5. S bit = 1 for light pen switch condition

This order can be used for any of the following functions, depending on the configuration of modifier bits in the first word:

Function	Mnemonic
Unconditional Branch	GB
Unconditional Branch, External	GBE
Conditional Branch	GBC
Conditional Branch, External	GBCE
Unconditional Interrupt	GI
Conditional Interrupt	GIC

Bits 4 and 5 of the first word identify the order function:

Bits 4 (I/B)	Bit 5 (N)	Function
0	0	Interrupt
1	0	Branch
0	1	2-word no-op
1	1	2-word no-op

If a branch or interrupt function is specified, the configuration of bits 14 and 15 (the D and S bits) determines whether the branch or interrupt is conditional:

Bit 14 (D)	Bit 15 (S)	Conditions
0	0	None (unconditional)
0	1	Light pen switch closed; detect or no detect
1	0	Light pen detect; switch open or closed
1	1	Switch closed and detect

When neither bit is set, the branch or interrupt is unconditional. When either or both bits are set, the detect status bit and/or the light pen switch bit in the device status word (DSW) is tested. If the tested bit(s) is not a 1 (as specified by a 1 in bit 14 and/or 15), the order is handled as a 2-word no-op. If the tested bit(s) is a 1, a branch or interrupt is performed. The detect status bit is reset after it is tested if a branch or interrupt is performed.

An interrupt order (either unconditional or conditional with condition(s) met) stops regeneration of the display program, sets the order controlled interrupt bit (bit 0) in the DSW, and initiates an interrupt request to the CPU. Note that a detect or detect-and-switch-closed interrupt can be initiated only when light pen interrupts are deferred (by a Set Pen Mode order); when light pen interrupts are not deferred, a detect causes an immediate interrupt. The CPU program normally responds to this interrupt with Read Status command, fetching the DSW and other data to determine the cause of the interrupt.

Before a branch order (either unconditional or conditional with condition(s) met) is executed, the status of bit 8 in the first word is checked. If this bit is 0 (direct addressing specified), the order causes a branch to the storage location specified by the address word in the order.

If indirect addressing is specified (bit 8 = 1), the branch destination is specified in the location addressed by the order. For example, if address N is identified in the second word of this order, the branch is to the location specified by the contents of address N.

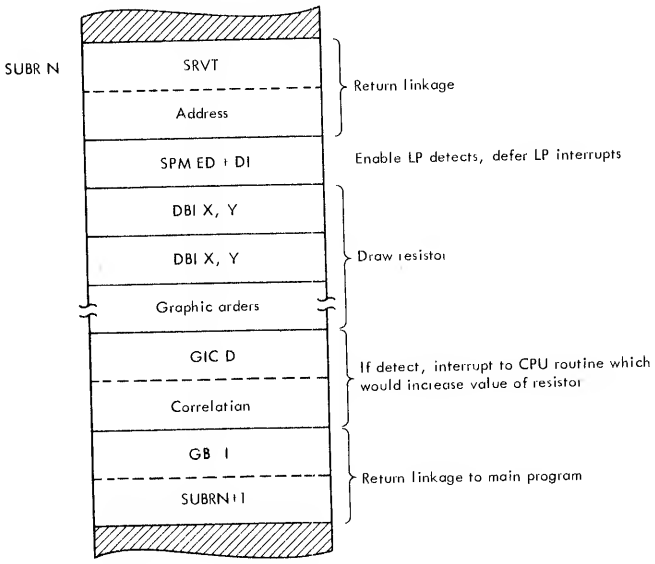
When a branch is executed, a 16-bit return address is saved in the revert register. (The return address is the address of the location that follows the Long Branch/Interrupt order location in storage.) This address is used (1) in Character mode when returning from the stroke table to the main program and (2) when executing a Revert order or a Store Revert Register order.

NOTE: A branch order must not specify an address that is beyond the physical limits of CPU storage; if it does, wraparound will occur. (The excess high-order address bits are ignored, and the remaining address bits specify the branch destination.)

When interrupt is specified, the second word of the order can be used by the programmer for specific graphic program identification data. For example, by interpreting a code in this field, the CPU can "simulate" functions not provided by the order set (e.g., Scale, Rotate, Translate, Count, etc.). This facility enables a user to customize the order set according to his application.

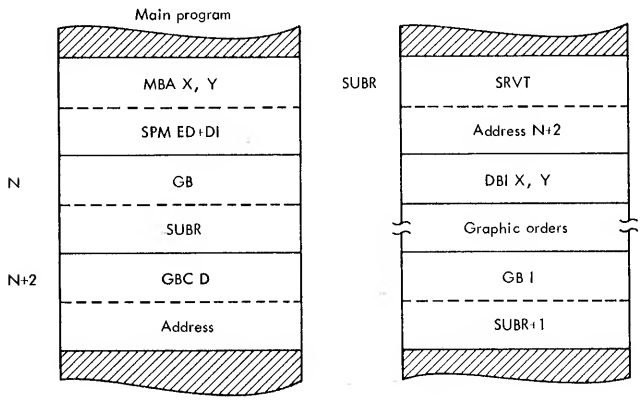
Each Conditional and Unconditional Branch External order (GBE and GBCE) causes a branch to an external order program. The second word of the order contains the symbolic name of the external program. The 1130 disk monitor creates a conditional branch (indirect addressing specified) to the named order program.

The following is an example of conditional interrupting in multiple-level subroutines:



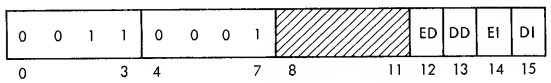
This subroutine example represents a resistor, and a light-pen detect condition indicates that the operator wishes to increase the value of the resistor by a specified amount. If a light-pen detect occurs during execution of this subroutine, a conditional interrupt on detect (GIC D) is taken to a CPU routine, which would increase the value of the resistor. Otherwise, an unconditional branch with indirect addressing specified provides the first leg of a return linkage to the main program. Note that the Set Pen Mode (SPM) order enables light-pen detects (ED) and defers light-pen interrupts (DI). If light-pen interrupts were not deferred, the first detect during execution of this subroutine would cause an immediate interrupt; thus, the conditional interrupt order would not be reached.

An example of how a conditional branch could be used to verify a light-pen detect to a graphic subroutine or entity is as follows:



Detects are enabled and light-pen interrupts deferred before branching to the subroutine. After the subroutine is executed, displaying an element or entity, the main program is re-entered, and a conditional branch order (GBC D) is executed. If a light-pen detect occurred during subroutine execution, a branch is executed to a verification subroutine.

Set Pen Mode (SPM, GNOP)



Notes:
1. Bit 12 = 1 to enable light pen detects.
2. Bit 13 = 1 to disable light pen detects.
3. Bit 14 = 1 to enable light pen detect interrupts.
4. Bit 15 = 1 to defer light pen detects interrupts.

This order establishes the mode of light-pen operation in the 2250. It can enable or disable light-pen detects and can enable or defer interrupts when a detect does occur. Deferred detects can be tested by Long Branch/Interrupt orders. Note that execution of a Reset Display command also resets Light Pen mode to disable light-pen detects and defer light-pen interrupts and resets the detect interrupt and detect status bits in the DSW.

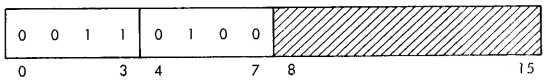
Light-pen switch operation is independent of light-pen detect circuitry. Switch status is sampled once per regeneration cycle. Long Branch/Interrupt orders, by testing the detect status and light pen switch DSW bits, can branch or interrupt as required to support light-pen operations.

A light pen mode is established by the status of bits 12-15 in the Set Pen Mode order. The possible combinations of these bits and the purpose of each combination are as follows:

1. Bits 12-15 = 0 1 X X (Disable Light Pen Detect): Inhibits a detect from setting the DSW detect status bit.
2. Bits 12-15 = 1 0 X X (Enable Light Pen Detects): Permits a detect to set the detect status bit.
3. Bits 12-15 = 0 0 X X or 1 1 X X: Light Pen Detect mode is not changed.
4. Bits 12-15 = X X 0 1 (Defer Light Pen Interrupts): Inhibits a Detect Interrupt from being generated when the DSW detect status bit is set, thereby allowing this status bit to be tested by a Long Branch/Interrupt order.
5. Bits 12-15 = X X 1 0 (Enable Light Pen Interrupts): Permits a Detect Interrupt to be generated when the DSW detect status bit is set. If the detect status bit is set when this Set Pen Mode order is decoded, an interrupt is generated immediately. The detect status bit is reset when the detect interrupt bit is set.
6. Bits 12-15 = X X 0 0 or X X 1 1: Light pen interrupt mode is not changed.
7. Bits 12-15 = 0000, 0011, 1100, 1111 (No Operation): The order is treated as a one-word no-op.

Programming Note: The configuration of all 0's in bits 8-15 of the Set Pen Mode order is reserved for the one-word no-op (GNOP) order.

Start Timer (STMR)



This order prevents the 2250 from using unnecessary storage cycles when executing a short display program, thereby freeing storage cycles for other programs. It is used with a branch order to control regeneration. (The branch order is necessary

to loop from the end of the display program to the beginning, thereby maintaining continuous regeneration without CPU program intervention.) The Start Timer order causes a 25ms timer to be tested. If the timer is running, storage accessing for information following the Start Timer order is delayed. When the timer stops, completing the current 25ms time period, it is restarted, and storage accessing automatically is resumed.

The Start Timer order should be included in each regeneration sequence. The regeneration rate is variable up to a rate of 40cps (25ms frame time) and is determined by the regeneration timer or by the amount of displayed information. (Messages that require less than 25ms to regenerate are displayed at the maximum rate of 40cps.) Note that a flicker-free display image can be obtained with a regeneration rate of 35 to 40cps.

The Start Timer order also allows keyboard interrupts and initiates testing of the light-pen switch. An alphameric or programmed function keyboard interrupt can be generated only during execution of a Start Timer order.

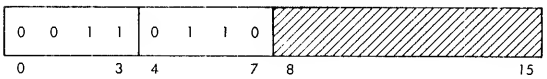
Programming Notes:

1. Failure to use a Start Timer order in a short display program may result in damage to the CRT screen or in variable intensity.
2. The Start Timer order should be used as the first order in a sequence of graphic orders that generates a particular display.

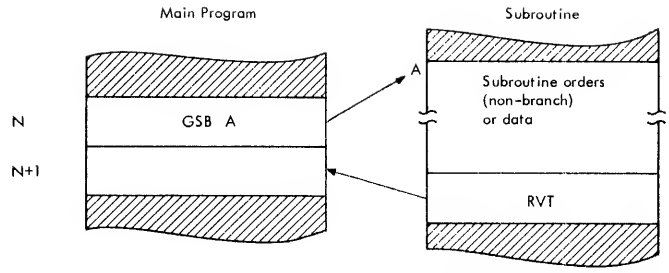
Subroutine Linkage Orders

Subroutine linkage in the display program is accomplished by means of a revert register. Each time a branch order is executed, a return address is saved in the revert register. This address points to the storage location following the location that contains the branch order. The return address is used by two orders: Revert and Store Revert Register.

Revert (RVT)

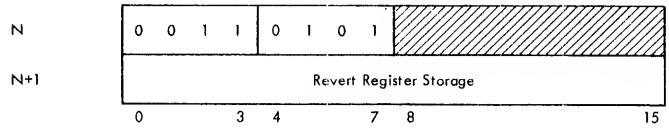


This order causes the revert register contents (the return address) to be loaded into the address register. It is used to return from a single-level subroutine, as follows:

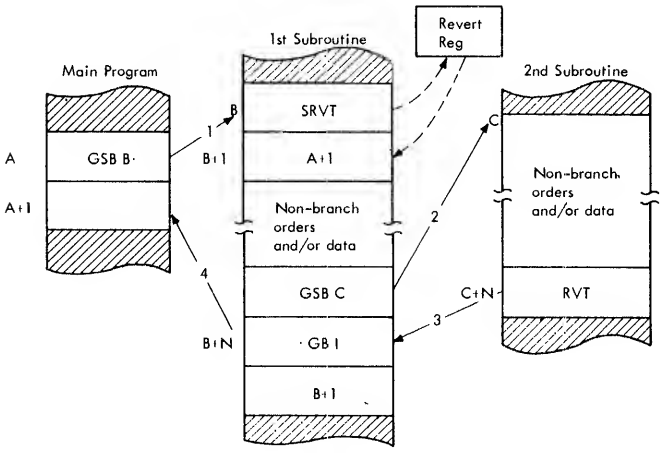


In this example, address N+1 is placed in the revert register as the Short Branch order is executed. This address is then placed in the address register when the Revert order is executed, effecting a return of operations to address N+1. Note that the same function is performed when the revert bit is set in a character data stroke word.

Store Revert Register (SRVT)



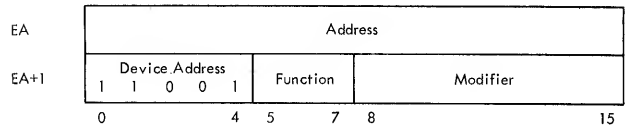
This order causes the revert register contents to be placed into storage as the second word of this order. It is used when more than one branch is to be executed before returning to the main program (i.e., for multilevel subroutining). For example, a Store Revert Register order would be executed before a second branch is issued. After the second branch, a third branch, with indirect addressing specified, can be used to return by way of the stored revert register contents as follows:



Since the revert register contents can be modified only by a branch order, interrupted subroutines can be restarted at the point of interrupt.

COMMANDS

The CPU uses I/O control commands (IOCC's) to control 2250-4 operations. An IOCC consists of two words, as follows:



The first word is at an even storage address and contains a 16-bit storage address. An IOCC must be at an even effective address (EA). The second word of the IOCC, stored in the next sequential location, is divided into three control fields: (1) the device address (25 decimal for the 2250-4), (2) the command function code, and (3) the command modifier code. When an Execute I/O (XIO) instruction is executed, the odd word of the IOCC is sent to the 2250, via the storage access channel, before the even word.

Seven functional commands can be executed by the 2250:

Function		Modifier	
Name	Code	Name	Code
Initiate Write	101	Start Regeneration	0--000--
Initiate Write	101	Set PF Indicators	1--000--
Initiate Read	110	Read Status	---000--
Control	100	No Operation	0--000--
Control	100	Reset Display	1--000--
Sense Interrupt	011	Sense Interrrupt	--------
Sense Device	111	Sense DSW	---000-R

Notes:

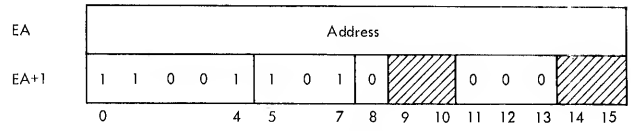
1. A dash (-) in the Modifier Code represents a bit that is not decoded by the 2250.
2. The "R" in the modifier code for Sense DSW is a 1 to reset interrupt request.

Command modifier bits 11, 12, and 13 must be 0's; unassigned modifier bits are not decoded. Unassigned function codes are treated as no-operation commands by the 2250. The execution time of each command is equal to the Execute I/O instruction time plus one core storage cycle time for each cycle steal required for data transfer.

Initiate Write

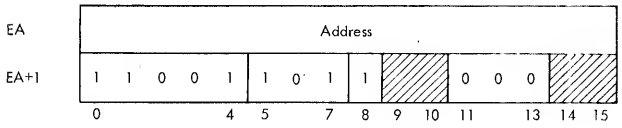
Both Initiate Write commands (Start Regeneration and Set Programmed Function Indicators) cause the corresponding even IOCC word (a 16-bit CPU storage address) to be loaded into the 2250 address register. Words are then accessed from CPU storage by cycle stealing, starting at this address. An Initiate Write command can be executed only when the 2250 is not busy (not regenerating) and is treated as a no-operation command when the 2250 is busy. A Reset Display command can be used to stop regeneration.

Start Regeneration



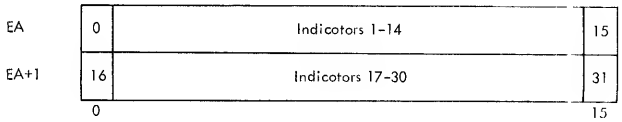
This command starts execution of the display program at the address specified in the even command word. Regeneration continues under control of orders in the display program until terminated by a Reset Display command or by a 2250 interrupt; the busy bit in the DSW is set during regeneration. The Start Regeneration command also clears the interrupt status indicators (DSW bits 0-2) and, if the keyboard interrupt bit is set, unlocks the 2250 keyboards, resets the data available bit, and clears Read Status command response words 4 and 5.

Set Programmed Function Indicators



This command is used to load the programmed function keyboard indicators with the contents of two consecutive words in CPU storage; the first of these two words is specified by the address word of this command. Two cycle-steal operations are performed.

Each bit in the two indicator words corresponds to one programmed function keyboard indicator, as follows:

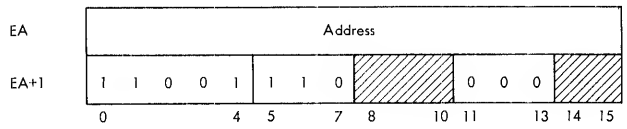


All 1 bits cause their associated indicators to light, and all 0 bits cause their associated indicators to be

turned off. No interrupts are generated.

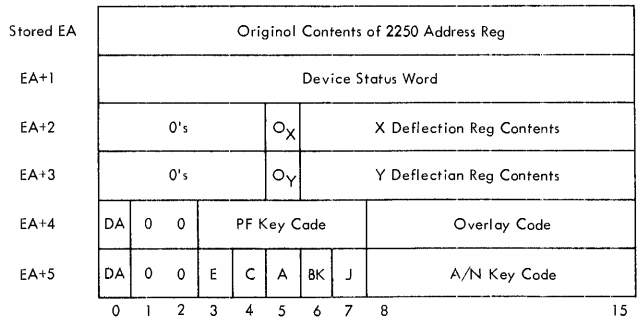
All programmed function indicators are turned off by a power-on reset (generated when 1130 power is turned on) and by a manual reset (generated when the 1131 RESET pushbutton is pressed). When a Reset Display command is executed, the odd word of the Reset Display IOCC (at EA+1) is imaged twice, once in indicators 0-15 and once in indicators 16-31.

Read Status



This command causes six words of 2250 status information to be placed, by cycle-stealing, into CPU storage, starting at the address specified in the command. The original contents of the 2250 address register are saved (as the first word of status information) before the command address word is loaded but are not restored after execution of the command.

A Read Status command is normally issued immediately after a Sense Interrupt command in response to a 2250 interrupt; however, it can be executed any time the 2250 is not busy. Interrupts are not generated by the Read Status command, and the 2250 interrupt request is reset (if set). The six words of status information read by this command are as follows:



Legend: O_X = X Overflow; O_Y = Y Overflow; DA = Dota Avoilable; E = End Key; C = Cancel Key; A = Advance Key; BK = Backspoce Key; J = Jump Key; PF = Pragrammed Functian Keyboord; A/N = Alphameric Keybaard

These words reflect the status of the address register, DSW, X and Y deflection registers, programmed function keyboard, and alphameric keyboard at the time of the preceding interrupt. If a keyboard is not attached to the 2250 or does not have data available, the appropriate data available bit (bit 0) will be a zero. The DSW contents are defined in the Sense DSW command description. The address register contents in the first word of this response, to be meaningful, may require modification as specified by address displacement bits 14 and 15 in the DSW. The Read Status response is further described in the Interrupts section of this document.

A deflection register overflow bit is 1 only when the beam is outside the visible image area; the beam is always blanked in this case. The beam can be moved outside the image area only during Incremental Graphic mode operations or during incrementally positioned Character mode operation. Once outside the image area, Short Absolute orders can move the beam without returning it to the image area.

In Incremental mode, the beam can be returned to the image area (Figure 4) by issuing (1) a Long Absolute Graphic mode order, (2) Incremental Graphic mode orders in the reverse direction, (3) one Short Absolute Graphic mode order if the beam is off the screen either vertically or horizontally (one overflow bit is set), or (4) two Short Absolute Graphic mode orders (both overflow bits are set). In Character mode, the beam can be returned by issuing a new line character control word (if the X overflow bit is set and execution of a new line function will not cause Y underflow) or by the same methods described in the preceding sentence for Incremental mode.

Keyboard data might be either in word 4 or in word 5 of the status information but not in both words at the same time. Bit 0 is set to 1 if data is available in the word. When one of the 32 programmed function keyboard keys has been depressed, bits 3-7 of word 4 contain a five-bit binary key code which corresponds to the depressed key. In addition, bits 8-15 contain an eight-bit binary code which represents one of 256 possible keyboard overlays.

Figure 12 is a drawing of an overlay. The circles on this overlay represent the holes through which the keys/indicators protrude. The number at the upper left of each circle is the code of the associated key/indicator; the binary configuration of this code for a key that has been depressed is used in bits 3-7 of word 4 as follows:

Depressed Key	Key Code (bits 3-7)
0	0 0 0 0 0
1	0 0 0 0 1
30	1 1 1 1 0
31	1 1 1 1 1

Located at the top edge of the overlay are notch positions, numbered 0 through 7. Bits 8-15 of word 4 are a direct image of the notches in the overlay being used; each 1 bit represents a notch in the corresponding overlay position, as follows:

Overlay Notch(es)	Overlay code (bits 8-15)
None	0 0 0 0 0 0 0 0
7	0 0 0 0 0 0 0 1
6	0 0 0 0 0 0 1 0
6, 7	0 0 0 0 0 0 1 1
0-6	1 1 1 1 1 1 1 0
0-7 or no overlay	1 1 1 1 1 1 1 1

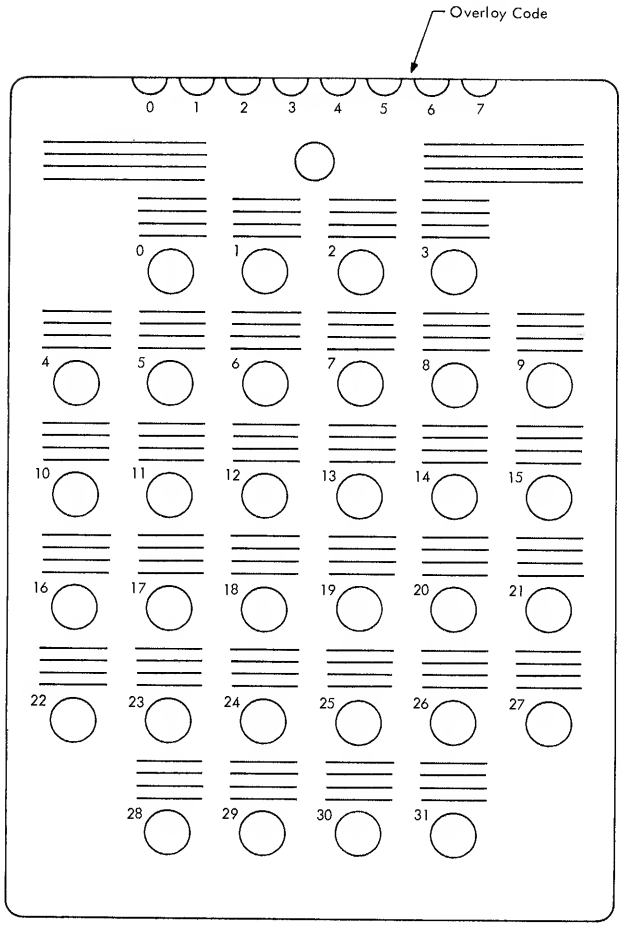


Figure 12. Programmed Function Keyboard Overlay (Top View)

Overlays can be marked by typewriter, ball-point pen, pencil, etc. A clear lacquer spray is suggested for fixing the markings on the overlay (to prevent smudging).

When an alphameric keyboard key has been depressed, word 5 of the status information identifies the depressed key and bit 0 is set to 1. Bits 3-7 identify the END, CANCEL, ADVANCE, BACKSPACE, and JUMP keys, respectively. If all of these bits are zero, a character key is identified by a code in bits 8-15. If any of bits 3-7 is a one, bits 8 to 15 will be zero. Figure 13 shows the possible codes (in hexadecimal) that can be in bits 8-15; bits 8-11 contain the first hexadecimal character, and bits 12-15 contain the second. For example, the code for "w" (A6) is 1010 0110 in bits 8-15.

Key Codes (Hexdecimal) (see note)

Bits 4-7 \ Bits 0 - 3	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL				SP	&	-									0
1							/		o	j			A	J		1
2									b	k	s		B	K	S	2
3									c	l	t		C	L	T	3
4									d	m	u		D	M	U	4
5									e	n	v		E	N	V	5
6									f	o	w		F	O	W	6
7									g	p	x		G	P	X	7
8									h	q	y		H	Q	Y	8
9									i	r	z		I	R	Z	9
A					¢	!		:								
B					.	$	,	#								
C					<	*	%	@								
D					(	)	_	'								
E					+	;	>	=								
F					|	¬	?	"								

Legend:
SP - Space
NUL - Null

Examples:

Character	Code
A	C1
9	F9
%	6C
NUL	00

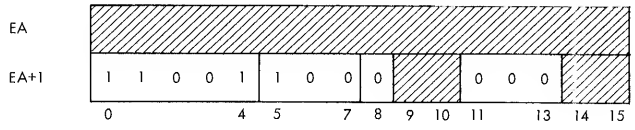
Note
Character code assignments other than those shown within the heavily outlined portions of the chart above are undefined. The characters that would be indicated by these codes are not specified. Also, a character that would be indicated by the 2250 Model 4 for a given undefined character code may be different for other devices. IBM reserves the right to change at any time the character indicated by the 2250 for an undefined character code.

Figure 13. Alphameric Keyboard Code Assignments

Control

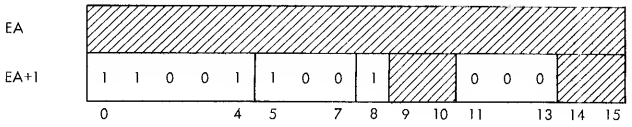
During control command execution, the 2250 address register is not loaded by an address from the IOCC, cycle steals are not used, and interrupts are not generated.

No-Operation



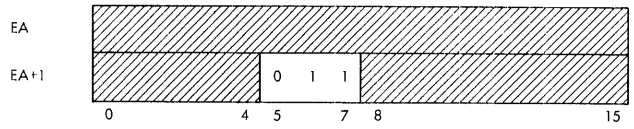
This command is ignored by the 2250. It is reserved as a no-operation and will not be assigned a function in the future.

Reset Display

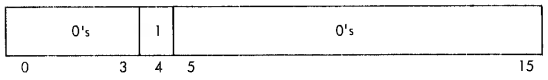


This command immediately stops regeneration and generates a unit reset in the 2250, causing all registers, controls, and keyboards to be reset. Zero is the reset state of all registers except the X and Y deflection registers, which are reset to 512 each (the center of the reference grid). The Display mode is reset to Graphic mode (vector), and light-pen control is reset to the disable-detects and defer-interrupts condition. In addition, all pending interrupts are cleared, and the 2250 is made not busy. In addition, the bit configuration in the odd word of the Reset Display IOCC (at EA+1) is imaged twice in the programmed function indicators, once in indicators 0-15, and again in indicators 16-31; each 1-bit lights two indicators, and each 0-bit clears two.

Sense Interrupt

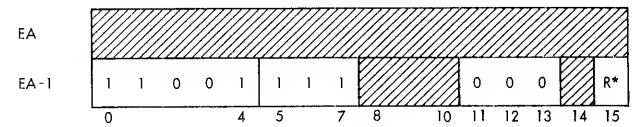


The 2250 executes this command (1) if the 2250 is requesting an interrupt and (2) if interrupt level 3 is active in the 1130. If these conditions are met, the 2250 sends the following word to the 1131:



At the 1131 accumulator, bit 4 is logically OR'ed into the level-3 interrupt level status word with bits from other devices with level-3 interrupts pending. The 1130 program responds to this interrupt (if the 2250 has highest priority) with a Read Status command to identify the interrupting condition. If an interrupt is not pending, or if interrupt level 3 is not active, the 2250 handles the Sense Interrupt command as a no-operation. Note that device address bits 0 to 4 are ignored at all times.

Sense DSW



* Reset (R): If set to 1, causes interrupt request to be reset.

This command causes the 2250 to send a device status word (DSW) to the 1131, where it is loaded into the accumulator. Cycle steals are not used, and interrupts are not generated. If the 2250 is regenerating (is busy), only bit 8 of the DSW is set When the 2250 is not busy, the DSW contents describe the control status of the 2250, as follows:

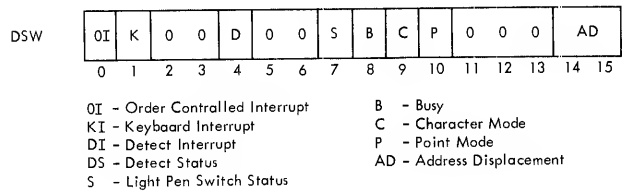


Table 2 gives the meaning of these bits.

Table 2. Interpretation of DSW

Bit(s)	Name	Indication
0	Order Controlled Interrupt	Long Branch/Interrupt order caused the interrupt.
1	Keyboard Interrupt	A key has been depressed on either keyboard, and data is available.
2	Detect Interrupt	Light pen has detected a point vector, or character with interrupts enabled.
3	Reserved (must be 0's)	
4	Detect Status	Light pen has detected a point, vector, or character with interrupts deferred. This bit is reset whenever it is tested successfully or when DSW bit 2 is set.
5, 6	Reserved (must be 0's)	
7	Light Pen Switch Status	Light pen switch was closed when last Start Timer order was executed.
8	Busy	Display is currently regenerating in Cycle Steal mode. This bit is always 0 if interrupt has occurred and/or display is not regenerating.
9	Character Mode	A 1 when in Basic or Large Character mode; 0 when in Graphic mode.
10	Point Mode	Significant if bit 9 = 0; bit 10 = 1 for Point mode, or = 0 for Vector mode.
11-13	Reserved (must be 0)	
14, 15	Address Displacement	Indicates number of locations the address register (in first word of read status response) is ahead of address of order being executed when Detect Interrupt occurred. Contains indeterminate value at any other time. Reset to 01.

NOTE: The DSW is reset to 0001_{16} by 2250 unit reset; DSW bits 0-4 are reset by a Start Regeneration command. A nonzero DSW indicates the 2250 is logically enabled (on-line).

INTERRUPTS

All interrupts stop regeneration and request a level-3 interrupt. When a Sense Interrupt command is executed and the 2250 has an interrupt, bit 4 is set in the level-3 interrupt level status word at the 1131 accumulator.

Following the interrupt, a Read Status command can be used to read the current contents of significant registers (six words in all) the CPU storage. The 2250 address register contents are in the first word of status information. This address always points the CPU storage location that would have been accessed next if the interrupt had not occurred. The significance of this address depends on the type of interrupt generated. In all cases, the DSW identifies the interrupt cause. The DSW is the second word of status information sent by the 2250 in response to a Read Status command and in the only response to a Sense DSW command. A Shift Left and Count instruction can be used by the 1131 program to interrupt the DSW because the left-most 1-bit identifies the interrupt.

Bits 0-2 of the DSW (the interrupt status) are reset by the next Start Regeneration command. The interrupt request is reset either by the Read Status command or by a Sense DSW command with bit 15 set to 1, whichever occurs first. An interrupt does not affect the current 2250 display mode (Graphic or Character) and does not change the contents of the revert register or the X and Y deflection registers.

Order Controlled Interrupt

A 1 in DSW bit 0 indicates the occurrence of an order controlled interrupt. This interrupt is generated when the 2250 is executing either the Unconditional or Conditional Interrupt variation of the Long Branch/Interrupt order; the Conditional Interrupt variation can cause an interrupt only when the light-pen detect and/or light-pen switch status bits are tested successfully by the order.

Following execution of a Read Status command, the address in the first word of status information points to the second word of the Long Branch/Interrupt order, which may contain an address or other interrupt identification data. Bits 4 and 7 of the DSW indicate the light-pen detect and light-pen switch status at the time of interrupt; bit 4 is reset after it is tested successfully.

Keyboard Interrupt

A 1 in DSW bit 1 indicates the occurrence of a keyboard interrupt. It is set when a key has been depressed either on the alphameric keyboard or on the programmed function keyboard and the next Start Timer order is decoded. A Read Status command reads the appropriate keyboard (response word 4 or 5). Both keyboards are locked and light-pen detects are inhibited at the time of interrupt; they remain in this condition until a Start Regeneration command is executed.

A keyboard interrupt can occur only during execution of a Start Timer order. If both keyboards are activated simultaneously, the programmed function keyboard is given priority by the 2250, causing the interrupt; in this case, the alphameric keyboard is locked out. Bits 4 and 7 of the DSW indicate the light-pen detect and light-pen switch status at the time of interrupt.

Following depression of an alphameric keyboard key other than SHIFT, LOCK, ALTN CODING, or CONTINUE, or following depression and release of a programmed function keyboard key, the following sequence occurs:

1. A data available bit is set in the DSW, and both keyboards are locked.
2. The next Start Timer order checks the data available bits and, since one is set, requests an interrupt and sets the keyboard interrupt bit in the DSW. At this time, regeneration is stopped, and the address register points to the Start Timer order location +1.
3. The CPU program should respond to this interrupt with a Read Status command. The 2250 response to this command includes the DSW, which identifies the interrupt, and a set data available bit, which identifies the interrupting keyboard and the response word that contains the keyboard information.
4. The next Start Regeneration command resets the keyboard interrupt bit in the DSW, resets both keyboard words in the Read Status command response (because a data available bit is set), and unlocks both keyboards.

Between the setting of a data available bit and receipt of a Start Timer order, if a light-pen or order-controlled interrupt occurs, the interrupt is taken. After the CPU program analyzes the Read Status command response for light-pen or order-associated information, it can examine the data available bits and satisfy the keyboard operation at the same time. Otherwise, when regeneration is started, the next Start Timer order will generate a Keyboard Interrupt.

Detect Interrupt

This interrupt is indicated by a 1 in DSW bit 2. It is generated when the 2250 is enabled for light-pen interrupts (by a Set Pen Mode order) and a detect has occurred.

When a detect occurs while the 2250 is not enabled for light pen-interrupts, execution of a Set Pen Mode order to enable interrupts causes an immediate interrupt unless the detect condition is reset before execution of the order. In this case, the address in the first read status response word will be one higher than the address of the Set Pen Mode order; therefore, bits 14 and 15 of the DSW (the address displacement bits) will be 0 and 1 respectively. Note that the detect status bit is always reset by a Detect Interrupt.

If the 2250 is enabled for light-pen detects when a detect occurs, the address in the first read status response word depends on the type of data detected. Bits 9 and 10 of the DSW identify the display mode ad Character, Vector, or Point. Bits 14 and 15 of the DSW specify a displacement. This displacement should be subtracted from the read status response word 0 contents to obtain the address of (1) the first, or only, graphic positioning order causing display of the detected element or (2) the branch order to the detected character. Light-pen switch status at the time read status was executed is indicated in DSW bit 7. In addition, the contents of the X and Y deflection registers (read status response words 2 and 3) might be significant.

If the light pen detects a character stroke, the light pen detect DSW bit is not set and the interrupt is not generated (1) until the Revert function, character space, and (if necessary) line space are completed, or (2), if not character space (e.g. a Null character follows), until the beam is repositioned to X = 000, Y = 000 of the character grid.

ERROR RECOVERY PROCEDURES

Two types of error procedures may be used for 2250 errors. The first is a programmed recovery procedure for errors detected by the program. The second is a manual recovery procedure for errors detected by the operator. Both involve a single retry.

The programmed recovery procedure consists of (1) issuing a Reset Display command and (2) restarting the display at the first order in the display order list. An error halt and optional error recording may follow an unsuccessful retry. This procedure can be used for the following error conditions when detected by the program.

1. 2250 fails to become busy after issuing a Start Regeneration command (DSW bit 8 = 0).
2. 2250 interrupts but remains busy (DSW bit 8 = 1).
3. 2250 interrupts, but no interrupt bits are set (DSW bits 0-2 are 0's).
4. Busy clear, but Read Status command fails to execute (no data transferred).
5. Reset command fails to clear busy or other DSW bits.
6. More than one interrupt bit set at same time.
7. Keyboard interrupt bit set, but no data available bits set in keyboard data words.
8. Both alphameric and programmed function keyboard data available on single interrupt.

The manual recovery procedure consists of (1) manually resetting the 1130/2250 system and, then, (2) either restarting or reloading the program, depending on the error detected. This procedure should be used for error conditions that can be detected by the operator but not by the program. The following errors require this procedure:

1. Display and CPU stop with the Parity Check light lit on the 1131. This indicates that a location in CPU storage, accessed either by the CPU or by the I/O device, contains bad parity. The program should be reloaded to continue after manually resetting the system.
2. 2250 and/or CPU program hangs up, but not as a result of a programmed stop. The manual procedure in this case is to reset the system and attempt a restart at a start-over point in the program or monitor. If this fails, reload the program.
3. 2250 manual input devices (light pen, alphameric keyboard, or programmed function keyboard) fail to interrupt the CPU and 2250, or the program appears to respond to a key code other than that manually entered. The initial recovery procedure here is to retry the failing input device. If this fails, reset the system and restart the program at a start-over point in the program or monitor.
4. 2250 displays a distorted or incorrect image on the screen. Reset the system and restart the program at a start-over point in the program or monitor.

An error-recording subroutine may be called in the event of an unsuccessful retry. This subroutine would be callable either by the graphic I/O subroutines or by the user. A Read Status command would be issued by this subroutine to recover 2250 status information; this information could then be printed with a core dump of significant program locations.

Since program errors can cause some, but not all, of the above error conditions, the programmer should recheck his program (if the above procedure fails) before calling the customer engineer.

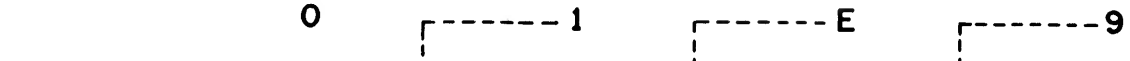
The table in this appendix provides for direct conversion of decimal and hexadecimal numbers in these ranges:

Hexadecimal	Decimal
000 to FFF	0000 to 4095

For numbers outside the range of the table, add the following values to the table figures:

Hexadecimal	Decimal
1000	4096
2000	8192
3000	12288

Hexadecimal	Decimal
4000	16384
5000	20480
6000	24576
7000	28672
8000	32768
9000	36864
A000	40960
B000	45056
C000	49152
D000	53248
E000	57344
F000	61440



	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00 _	0000	0001	0002	0003	0004	0005	0006	0007	0008	0009	0010	0011	0012	0013	0014	0015
01 _	0016	0017	0018	0019	0020	0021	0022	0023	0024	0025	0026	0027	0028	0029	0030	0031
02 _	0032	0033	0034	0035	0036	0037	0038	0039	0040	0041	0042	0043	0044	0045	0046	0047
03 _	0048	0049	0050	0051	0052	0053	0054	0055	0056	0057	0058	0059	0060	0061	0062	0063
04 _	0064	0065	0066	0067	0068	0069	0070	0071	0072	0073	0074	0075	0076	0077	0078	0079
05 _	0080	0081	0082	0083	0084	0085	0086	0087	0088	0089	0090	0091	0092	0093	0094	0095
06 _	0096	0097	0098	0099	0100	0101	0102	0103	0104	0105	0106	0107	0108	0109	0110	0111
07 _	0112	0113	0114	0115	0116	0117	0118	0119	0120	0121	0122	0123	0124	0125	0126	0127
08 _	0128	0129	0130	0131	0132	0133	0134	0135	0136	0137	0138	0139	0140	0141	0142	0143
09 _	0144	0145	0146	0147	0148	0149	0150	0151	0152	0153	0154	0155	0156	0157	0158	0159
0A _	0160	0161	0162	0163	0164	0165	0166	0167	0168	0169	0170	0171	0172	0173	0174	0175
0B _	0176	0177	0178	0179	0180	0181	0182	0183	0184	0185	0186	0187	0188	0189	0190	0191
0C _	0192	0193	0194	0195	0196	0197	0198	0199	0200	0201	0202	0203	0204	0205	0206	0207
0D _	0208	0209	0210	0211	0212	0213	0214	0215	0216	0217	0218	0219	0220	0221	0222	0223
0E _	0224	0225	0226	0227	0228	0229	0230	0231	0232	0233	0234	0235	0236	0237	0238	0239
0F _	0240	0241	0242	0243	0244	0245	0246	0247	0248	0249	0250	0251	0252	0253	0254	0255
10 _	0256	0257	0258	0259	0260	0261	0262	0263	0264	0265	0266	0267	0268	0269	0270	0271
11 _	0272	0273	0274	0275	0276	0277	0278	0279	0280	0281	0282	0283	0284	0285	0286	0287
12 _	0288	0289	0290	0291	0292	0293	0294	0295	0296	0297	0298	0299	0300	0301	0302	0303
13 _	0304	0305	0306	0307	0308	0309	0310	0311	0312	0313	0314	0315	0316	0317	0318	0319
14 _	0320	0321	0322	0323	0324	0325	0326	0327	0328	0329	0330	0331	0332	0333	0334	0335
15 _	0336	0337	0338	0339	0340	0341	0342	0343	0344	0345	0346	0347	0348	0349	0350	0351
16 _	0352	0353	0354	0355	0356	0357	0358	0359	0360	0361	0362	0363	0364	0365	0366	0367
17 _	0368	0369	0370	0371	0372	0373	0374	0375	0376	0377	0378	0379	0380	0381	0382	0383
18 _	0384	0385	0386	0387	0388	0389	0390	0391	0392	0393	0394	0395	0396	0397	0398	0399
19 _	0400	0401	0402	0403	0404	0405	0406	0407	0408	0409	0410	0411	0412	0413	0414	0415
1A _	0416	0417	0418	0419	0420	0421	0422	0423	0424	0425	0426	0427	0428	0429	0430	0431
1B _	0432	0433	0434	0435	0436	0437	0438	0439	0440	0441	0442	0443	0444	0445	0446	0447
1C _	0448	0449	0450	0451	0452	0453	0454	0455	0456	0457	0458	0459	0460	0461	0462	0463
1D _	0464	0465	0466	0467	0468	0469	0470	0471	0472	0473	0474	0475	0476	0477	0478	0479
1E _	0480	0481	0482	0483	0484	0485	0486	0487	0488	0489	0490	0491	0492	0493	0494	0495
1F _	0496	0497	0498	0499	0500	0501	0502	0503	0504	0505	0506	0507	0508	0509	0510	0511

11313

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
20 _	0512	0513	0514	0515	0516	0517	0518	0519	0520	0521	0522	0523	0524	0525	0526	0527
21 _	0528	0529	0530	0531	0532	0533	0534	0535	0536	0537	0538	0539	0540	0541	0542	0543
22 _	0544	0545	0546	0547	0548	0549	0550	0551	0552	0553	0554	0555	0556	0557	0558	0559
23 _	0560	0561	0562	0563	0564	0565	0566	0567	0568	0569	0570	0571	0572	0573	0574	0575
24 _	0576	0577	0578	0579	0580	0581	0582	0583	0584	0585	0586	0587	0588	0589	0590	0591
25 _	0592	0593	0594	0595	0596	0597	0598	0599	0600	0601	0602	0603	0604	0605	0606	0607
26 _	0608	0609	0610	0611	0612	0613	0614	0615	0616	0617	0618	0619	0620	0621	0622	0623
27 _	0624	0625	0626	0627	0628	0629	0630	0631	0632	0633	0634	0635	0636	0637	0638	0639
28 _	0640	0641	0642	0643	0644	0645	0646	0647	0648	0649	0650	0651	0652	0653	0654	0655
29 _	0656	0657	0658	0659	0660	0661	0662	0663	0664	0665	0666	0667	0668	0669	0670	0671
2A _	0672	0673	0674	0675	0676	0677	0678	0679	0680	0681	0682	0683	0684	0685	0686	0687
2B _	0688	0689	0690	0691	0692	0693	0694	0695	0696	0697	0698	0699	0700	0701	0702	0703
2C _	0704	0705	0706	0707	0708	0709	0710	0711	0712	0713	0714	0715	0716	0717	0718	0719
2D _	0720	0721	0722	0723	0724	0725	0726	0727	0728	0729	0730	0731	0732	0733	0734	0735
2E _	0736	0737	0738	0739	0740	0741	0742	0743	0744	0745	0746	0747	0748	0749	0750	0751
2F _	0752	0753	0754	0755	0756	0757	0758	0759	0760	0761	0762	0763	0764	0765	0766	0767
30 _	0768	0769	0770	0771	0772	0773	0774	0775	0776	0777	0778	0779	0780	0781	0782	0783
31 _	0784	0785	0786	0787	0788	0789	0790	0791	0792	0793	0794	0795	0796	0797	0798	0799
32 _	0800	0801	0802	0803	0804	0805	0806	0807	0808	0809	0810	0811	0812	0813	0814	0815
33 _	0816	0817	0818	0819	0820	0821	0822	0823	0824	0825	0826	0827	0828	0829	0830	0831
34 _	0832	0833	0834	0835	0836	0837	0838	0839	0840	0841	0842	0843	0844	0845	0846	0847
35 _	0848	0849	0850	0851	0852	0853	0854	0855	0856	0857	0858	0859	0860	0861	0862	0863
36 _	0864	0865	0866	0867	0868	0869	0870	0871	0872	0873	0874	0875	0876	0877	0878	0879
37 _	0880	0881	0882	0883	0884	0885	0886	0887	0888	0889	0890	0891	0892	0893	0894	0895
38 _	0896	0897	0898	0899	0900	0901	0902	0903	0904	0905	0906	0907	0908	0909	0910	0911
39 _	0912	0913	0914	0915	0916	0917	0918	0919	0920	0921	0922	0923	0924	0925	0926	0927
3A _	0928	0929	0930	0931	0932	0933	0934	0935	0936	0937	0938	0939	0940	0941	0942	0943
3B _	0944	0945	0946	0947	0948	0949	0950	0951	0952	0953	0954	0955	0956	0957	0958	0959
3C _	0960	0961	0962	0963	0964	0965	0966	0967	0968	0969	0970	0971	0972	0973	0974	0975
3D _	0976	0977	0978	0979	0980	0981	0982	0983	0984	0985	0986	0987	0988	0989	0990	0991
3E _	0992	0993	0994	0995	0996	0997	0998	0999	1000	1001	1002	1003	1004	1005	1006	1007
3F _	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023

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40 _	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039
41 _	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055
42 _	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071
43 _	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087
44 _	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103
45 _	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119
46 _	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135
47 _	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151
48 _	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167
49 _	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183
4A _	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199
4B _	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215
4C _	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231
4D _	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247
4E _	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263
4F _	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279
50 _	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295
51 _	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311
52 _	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327
53 _	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343
54 _	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359
55 _	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375
56 _	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391
57 _	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407
58 _	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423
59 _	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439
5A _	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455
5B _	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471
5C _	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487
5D _	1488	1489	1490	1491	1492	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	1503
5E _	1504	1505	1506	1507	1508	1509	1510	1511	1512	1513	1514	1515	1516	1517	1518	1519
5F _	1520	1521	1522	1523	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533	1534	1535

11314

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61_	1552	1553	1554	1555	1556	1557	1558	1559	1560	1561	1562	1563	1564	1565	1566	1567
62_	1568	1569	1570	1571	1572	1573	1574	1575	1576	1577	1578	1579	1580	1581	1582	1583
63_	1584	1585	1586	1587	1588	1589	1590	1591	1592	1593	1594	1595	1596	1597	1598	1599
64_	1600	1601	1602	1603	1604	1605	1606	1607	1608	1609	1610	1611	1612	1613	1614	1615
65_	1616	1617	1618	1619	1620	1621	1622	1623	1624	1625	1626	1627	1628	1629	1630	1631
66_	1632	1633	1634	1635	1636	1637	1638	1639	1640	1641	1642	1643	1644	1645	1646	1647
67_	1648	1649	1650	1651	1652	1653	1654	1655	1656	1657	1658	1659	1660	1661	1662	1663
68_	1664	1665	1666	1667	1668	1669	1670	1671	1672	1673	1674	1675	1676	1677	1678	1679
69_	1680	1681	1682	1683	1684	1685	1686	1687	1688	1689	1690	1691	1692	1693	1694	1695
6A_	1696	1697	1698	1699	1700	1701	1702	1703	1704	1705	1706	1707	1708	1709	1710	1711
6B_	1712	1713	1714	1715	1716	1717	1718	1719	1720	1721	1722	1723	1724	1725	1726	1727
6C_	1728	1729	1730	1731	1732	1733	1734	1735	1736	1737	1738	1739	1740	1741	1742	1743
6D_	1744	1745	1746	1747	1748	1749	1750	1751	1752	1753	1754	1755	1756	1757	1758	1759
6E_	1760	1761	1762	1763	1764	1765	1766	1767	1768	1769	1770	1771	1772	1773	1774	1775
6F_	1776	1777	1778	1779	1780	1781	1782	1783	1784	1785	1786	1787	1788	1789	1790	1791
70_	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802	1803	1804	1805	1806	1807
71_	1808	1809	1810	1811	1812	1813	1814	1815	1816	1817	1818	1819	1820	1821	1822	1823
72_	1824	1825	1826	1827	1828	1829	1830	1831	1832	1833	1834	1835	1836	1837	1838	1839
73_	1840	1841	1842	1843	1844	1845	1846	1847	1848	1849	1850	1851	1852	1853	1854	1855
74_	1856	1857	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869	1870	1871
75_	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887
76_	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903
77_	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
78_	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
79_	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
7A_	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
7B_	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
7C_	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
7D_	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
7E_	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
7F_	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047

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80_	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063
81_	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079
82_	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095
83_	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111
84_	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127
85_	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143
86_	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159
87_	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175
88_	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191
89_	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207
8A_	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223
8B_	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239
8C_	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255
8D_	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271
8E_	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287
8F_	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303
90_	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319
91_	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335
92_	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351
93_	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367
94_	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383
95_	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399
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97_	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431
98_	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447
99_	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463
9A_	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479
9B_	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495
9C_	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511
9D_	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527
9E_	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543
9F_	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559

11315

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A0 _	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575
A1 _	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591
A2 _	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607
A3 _	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623
A4 _	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639
A5 _	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655
A6 _	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671
A7 _	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687
A8 _	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703
A9 _	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719
AA _	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735
AB _	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751
AC _	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767
AD _	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783
AE _	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799
AF _	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815
B0 _	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831
B1 _	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847
B2 _	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863
B3 _	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879
B4 _	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895
B5 _	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911
B6 _	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927
B7 _	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943
B8 _	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959
B9 _	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975
BA _	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	2991
BB _	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005	3006	3007
BC _	3008	3009	3010	3011	3012	3013	3014	3015	3016	3017	3018	3019	3020	3021	3022	3023
BD _	3024	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	3035	3036	3037	3038	3039
BE _	3040	3041	3042	3043	3044	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054	3055
BF _	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070	3071

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C0 _	3072	3073	3074	3075	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086	3087
C1 _	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102	3103
C2 _	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118	3119
C3 _	3120	3121	3122	3123	3124	3125	3126	3127	3128	3129	3130	3131	3132	3133	3134	3135
C4 _	3136	3137	3138	3139	3140	3141	3142	3143	3144	3145	3146	3147	3148	3149	3150	3151
C5 _	3152	3153	3154	3155	3156	3157	3158	3159	3160	3161	3162	3163	3164	3165	3166	3167
C6 _	3168	3169	3170	3171	3172	3173	3174	3175	3176	3177	3178	3179	3180	3181	3182	3183
C7 _	3184	3185	3186	3187	3188	3189	3190	3191	3192	3193	3194	3195	3196	3197	3198	3199
C8 _	3200	3201	3202	3203	3204	3205	3206	3207	3208	3209	3210	3211	3212	3213	3214	3215
C9 _	3216	3217	3218	3219	3220	3221	3222	3223	3224	3225	3226	3227	3228	3229	3230	3231
CA _	3232	3233	3234	3235	3236	3237	3238	3239	3240	3241	3242	3243	3244	3245	3246	3247
CB _	3248	3249	3250	3251	3252	3253	3254	3255	3256	3257	3258	3259	3260	3261	3262	3263
CC _	3264	3265	3266	3267	3268	3269	3270	3271	3272	3273	3274	3275	3276	3277	3278	3279
CD _	3280	3281	3282	3283	3284	3285	3286	3287	3288	3289	3290	3291	3292	3293	3294	3295
CE _	3296	3297	3298	3299	3300	3301	3302	3303	3304	3305	3306	3307	3308	3309	3310	3311
CF _	3312	3313	3314	3315	3316	3317	3318	3319	3320	3321	3322	3323	3324	3325	3326	3327
D0 _	3328	3329	3330	3331	3332	3333	3334	3335	3336	3337	3338	3339	3340	3341	3342	3343
D1 _	3344	3345	3346	3347	3348	3349	3350	3351	3352	3353	3354	3355	3356	3357	3358	3359
D2 _	3360	3361	3362	3363	3364	3365	3366	3367	3368	3369	3370	3371	3372	3373	3374	3375
D3 _	3376	3377	3378	3379	3380	3381	3382	3383	3384	3385	3386	3387	3388	3389	3390	3391
D4 _	3392	3393	3394	3395	3396	3397	3398	3399	3400	3401	3402	3403	3404	3405	3406	3407
D5 _	3408	3409	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420	3421	3422	3423
D6 _	3424	3425	3426	3427	3428	3429	3430	3431	3432	3433	3434	3435	3436	3437	3438	3439
D7 _	3440	3441	3442	3443	3444	3445	3446	3447	3448	3449	3450	3451	3452	3453	3454	3455
D8 _	3456	3457	3458	3459	3460	3461	3462	3463	3464	3465	3466	3467	3468	3469	3470	3471
D9 _	3472	3473	3474	3475	3476	3477	3478	3479	3480	3481	3482	3483	3484	3485	3486	3487
DA _	3488	3489	3490	3491	3492	3493	3494	3495	3496	3497	3498	3499	3500	3501	3502	3503
DB _	3504	3505	3506	3507	3508	3509	3510	3511	3512	3513	3514	3515	3516	3517	3518	3519
DC _	3520	3521	3522	3523	3524	3525	3526	3527	3528	3529	3530	3531	3532	3533	3534	3535
DD _	3536	3537	3538	3539	3540	3541	3542	3543	3544	3545	3546	3547	3548	3549	3550	3551
DE _	3552	3553	3554	3555	3556	3557	3558	3559	3560	3561	3562	3563	3564	3565	3566	3567
DF _	3568	3569	3570	3571	3572	3573	3574	3575	3576	3577	3578	3579	3580	3581	3582	3583

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	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
E0_	3584	3585	3586	3587	3583	3589	3590	3591	3592	3593	3594	3595	3596	3597	3598	3599
E1_	3600	3601	3602	3603	3604	3605	3606	3607	3608	3609	3610	3611	3612	3613	3614	3615
E2_	3616	3617	3618	3619	3620	3621	3622	3623	3624	3625	3626	3627	3628	3629	3630	3631
E3_	3632	3633	3634	3635	3636	3637	3638	3639	3640	3641	3642	3643	3644	3645	3646	3647
E4_	3648	3649	3650	3651	3652	3653	3654	3655	3656	3657	3658	3659	3660	3661	3662	3663
E5_	3664	3665	3666	3667	3668	3669	3670	3671	3672	3673	3674	3675	3676	3677	3678	3679
E6_	3680	3681	3682	3683	3684	3685	3686	3687	3688	3689	3690	3691	3692	3693	3694	3695
E7_	3696	3697	3698	3699	3700	3701	3702	3703	3704	3705	3706	3707	3708	3709	3710	3711
E8_	3712	3713	3714	3715	3716	3717	3718	3719	3720	3721	3722	3723	3724	3725	3726	3727
E9_	3728	3729	3730	3731	3732	3733	3734	3735	3736	3737	3738	3739	3740	3741	3742	3743
EA_	3744	3745	3746	3747	3748	3749	3750	3751	3752	3753	3754	3755	3756	3757	3758	3759
EB_	3760	3761	3762	3763	3764	3765	3766	3767	3768	3769	3770	3771	3772	3773	3774	3775
EC_	3776	3777	3778	3779	3780	3781	3782	3783	3784	3785	3786	3787	3788	3789	3790	3791
ED_	3792	3793	3794	3795	3796	3797	3798	3799	3800	3801	3802	3803	3804	3805	3806	3807
EE_	3808	3809	3810	3811	3812	3813	3814	3815	3816	3817	3818	3819	3820	3821	3822	3823
EF_	3824	3825	3826	3827	3828	3829	3830	3831	3832	3833	3834	3835	3836	3837	3838	3839
F0_	3840	3841	3842	3843	3844	3845	3846	3847	3848	3849	3850	3851	3852	3853	3854	3855
F1_	3856	3857	3858	3859	3860	3861	3862	3863	3864	3865	3866	3867	3868	3869	3870	3871
F2_	3872	3873	3874	3875	3876	3877	3878	3879	3880	3881	3882	3883	3884	3885	3886	3887
F3_	3888	3889	3890	3891	3892	3893	3894	3895	3896	3897	3898	3899	3900	3901	3902	3903
F4_	3904	3905	3906	3907	3908	3909	3910	3911	3912	3913	3914	3915	3916	3917	3918	3919
F5_	3920	3921	3922	3923	3924	3925	3926	3927	3928	3929	3930	3931	3932	3933	3934	3935
F6_	3936	3937	3938	3939	3940	3941	3942	3943	3944	3945	3946	3947	3948	3949	3950	3951
F7_	3952	3953	3954	3955	3956	3957	3958	3959	3960	3961	3962	3963	3964	3965	3966	3967
F8_	3968	3969	3970	3971	3972	3973	3974	3975	3976	3977	3978	3979	3980	3981	3982	3983
F9_	3984	3985	3986	3987	3988	3989	3990	3991	3992	3993	3994	3995	3996	3997	3998	3999
FA_	4000	4001	4002	4003	4004	4005	4006	4007	4008	4009	4010	4011	4012	4013	4014	4015
FB_	4016	4017	4018	4019	4020	4021	4022	4023	4024	4025	4026	4027	4028	4029	4030	4031
FC_	4032	4033	4034	4035	4036	4037	4038	4039	4040	4041	4042	4043	4044	4045	4046	4047
FD_	4048	4049	4050	4051	4052	4053	4054	4055	4056	4057	4058	4059	4060	4061	4062	4063
FE_	4064	4065	4066	4067	4068	4069	4070	4071	4072	4073	4074	4075	4076	4077	4078	4079
FF_	4080	4081	4082	4083	4084	4085	4086	4087	4088	4089	4090	4091	4092	4093	4094	4095

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INCLUSION OF INDEX
IBM 1130 COMPUTING SYSTEM COMPONENT DESCRIPTION
IBM 2250 DISPLAY UNIT MODEL 4
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Insert new pages 38 and 39 and update the Contents page by adding "INDEX------38" under "APPENDIX A. HEXADECIMAL-DECIMAL CONVERSION---33". Also insert revised page 17, on which the format of Table 1 has been revised; (note that the technical content of this page is unchanged).

File this newsletter at the back of the publication. It will provide a reference to changes, a method of determining that all amendments have been received, and a check for determining whether the publication contains the proper changes.

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CORRECTION TO IBM SYSTEM/360 COMPONENT DESCRIPTION, IBM 2250 DISPLAY UNIT MODEL 4, FORM A27-2723-0

Replace page 25 with the page attached to this Newsletter. An error in the Set Pen Mode order bit configuration is corrected (bit 6 is changed to equal 0); this correction is indicated by a vertical line to the left of the change.

File this cover letter at the back of the publication. It will then serve as a record of changes received and incorporated.

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GENERAL

The 2250-4 channel interface section (Figure 2) interfaces the storage access channel and the 2250-4 display section. It decodes and executes orders and commands, addresses CPU storage, and handles data transferred to or from CPU storage. Information transfer across the storage access channel/2250 interface is by 16-bit word.

An address register in the 2250 channel section specifies, to CPU storage, the location at which information will be stored or from which it will be retrieved for 2250 operations. This address register is loaded initially by an Initiate Write (Start Regeneration) command from the CPU program; it can then be stepped automatically by the 2250, altered by the display program, or reloaded by the CPU program. Thus, display regeneration can be performed without CPU intervention.

The display program consists of display orders, associated data for image generation, and control orders for various nondisplay functions. Table 1 lists the 2250 order set. Undefined order codes received by the 2250 are treated as no-operation orders or are interpreted as data if in the appropriate format.

Table 1. 2250-4 Order Set

Type	Name	Variation(s)	Mnemonic	Comments
Display Orders	Set Graphic Mode	Vector	SGMV	
		Point	SGMP	
	Long Absolute XY	Absolute XY	DBA	Beam on
		Absolute XY	MBA	Beam off
	Short Absolute X/Y	Absolute X	DBAX	Beam on, X deflection
		Absolute X	MBAX	Beam off, X deflection
		Absolute Y	DBAY	Beam on, Y deflection
		Absolute Y	MBAY	Beam off, Y deflection
	Incremental XY	Incremental XY	DBI	Beam on
		Incremental XY	MBI	Beam off
	Set Character Mode	Basic	SCMB	
		Large	SCML	
Data Words	Character Stroke Word (2-stroke mnemonics generate one stroke word)	Stroke	DBS	Beam on
		Stroke	MBS	Beam off
		Control Word	CS	Control code
Control Orders	Short Branch		GSB	One Word
	Long Branch/ Interrupt	Unconditional Branch	GB	All variations are two words, and can be coded as 2-word no-op. Long Branches can be direct or indirect.
		Unconditional Branch, External	GBE	
		Conditional Branch,	GBC	
		Conditional Branch, External	GBCE	
		Unconditional Interrupt	GI	
		Conditional Interrupt	GIC	
	Set Pen Mode	Set Pen Mode	SPM	Several options selected by modifiers.
		Graphic No-Operation	GNOP	
	Start Timer		STMR	
	Revert		RVT	
	Store Revert Register		SRVT	

NOTE: The mnemonics shown are those used by the IBM 1130 Disk Monitor Assembler.

The CPU program initiates 2250 operations by issuing an Execute I/O (XIO) instruction. The I/O Control command (IOCC) at the effective storage address specified by XIO is then sent to the 2250. If the IOCC is Initiate Write (Start Regeneration), the 2250 fetches display program information from main storage, starting at the IOCC-specified address.

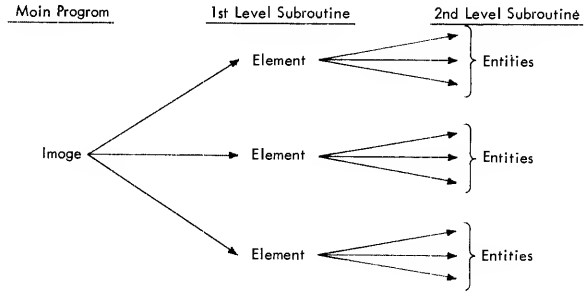
Display program information consists of orders and data. Orders either initiate a 2250 operation or establish a mode. Order-initiated operations include point and vector plotting, branching, and CPU interrupt generation. Two orders, Set Graphic Mode and Set Pen Mode, establish a Graphic mode and a Light Pen mode respectively. The 2250 is always in one of two Graphic modes and in one of four Light Pen modes.

Data is defined as information that does not contain an operation code. Character stroke words are the only data received by the 2250. Although a character stroke word may contain one or more control bits, these bits are used directly to perform an operation.

SUBROUTINES

Single-level subroutines (linkage from the main order program to the order subroutine and return to the main order program) are used frequently in graphic application. Thus, facilities for a rapid (unconditional) branch to a subroutine and return from the subroutine are provided. Since characters are similar to single-level subroutines, rapid branching significantly reduces character display time.

Orders in the display program enable multiple-level subroutine linkages to be performed. A single-level subroutine facility does not allow characters to be displayed as part of a subroutine, nor does it permit the organization of an image in a hierarchy of graphic segments represented by multiple-level subroutines, as follows:



Notes: 1. Examples of elements are elevation, plan, and end-views of a part.
2. Examples of entities are bolt heads, brackets, and supports.

Each graphic sub-picture (element) and each entity can be represented as a subroutine. This is useful in representing display images and performing manipulations on them. The multiple-level subroutine linkage is accomplished by:

1. Storing the return address (i.e., the address of the order following a branch order) in a particular core storage location.
2. Branching indirectly to the location of the return address; thus, the ultimate branch would be the next-higher subroutine level.

Graphic Subroutines

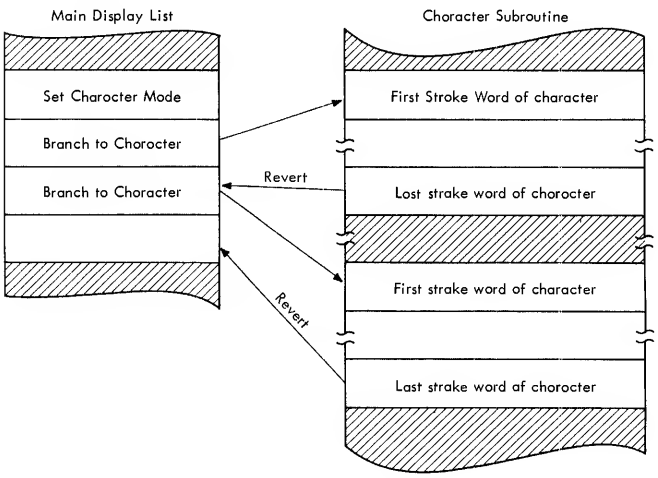
A graphic subroutine is a sequence of display orders which forms a logical element of entity. This method of graphic data organization substantially improves the efficiency of the CPU in the generation of graphic data. For example, the generation program can insert a vector to position the beam and then can provide a linkage to a subroutine representing a logic block in a logic diagram.

Using incremental vectors, the subroutine can generate a display of the logic block about the original reference point; then, linkage can be made back to the main sequence of display orders. The alternative is to require the CPU to place a copy of the logic block orders in the main graphic order sequence every time it appears in the displayed image. Consequently, the graphic subroutine capability substantially reduces storage requirements in instances where an image entity appears repetitively in a display.

In applications where the display images comprise groups of elements (e.g., resistors, capacitors, logic blocks, etc.), graphic subroutines, together with the "defer light pen interrupt" light-pen control order, allow the correlation of a light-pen detect with a group of elements. In many cases, identification of the group is required, rather than the particular element in the group which was detected.

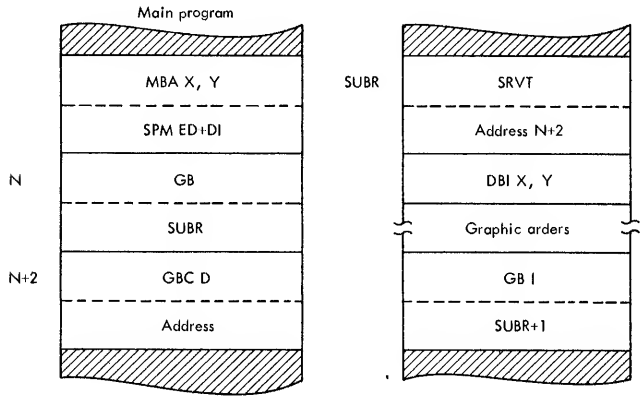
Character Generation

Character generation is a programmable function, allowing the user complete flexibility in the generation and use of character sets. Characters represented by their component strokes are stored in 1130 storage. Up to two character strokes are contained within the 16-bit 1130 word. The character stroke words are organized so that each character can be represented by a subroutine of stroke words. Characters, then, can be drawn by the following general sequence of display orders:



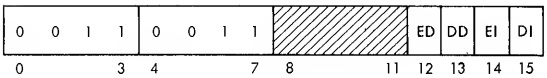
This subroutine example represents a resistor, and a light-pen detect condition indicates that the operator wishes to increase the value of the resistor by a specified amount. If a light-pen detect occurs during execution of this subroutine, a conditional interrupt on detect (GIC D) is taken to a CPU routine, which would increase the value of the resistor. Otherwise, an unconditional branch with indirect addressing specified provides the first leg of a return linkage to the main program. Note that the Set Pen Mode (SPM) order enables light-pen detects (ED) and defers light-pen interrupts (DI). If light-pen interrupts were not deferred, the first detect during execution of this subroutine would cause an immediate interrupt; thus, the conditional interrupt order would not be reached.

An example of how a conditional branch could be used to verify a light-pen detect to a graphic subroutine or entity is as follows:



Detects are enabled and light-pen interrupts deferred before branching to the subroutine. After the subroutine is executed, displaying an element or entity, the main program is re-entered, and a conditional branch order (GBC D) is executed. If a light-pen detect occurred during subroutine execution, a branch is executed to a verification subroutine.

Set Pen Mode (SPM, GNOP)



Notes:
1. Bit 12 = 1 to enable light pen detects.
2. Bit 13 = 1 to disable light pen detects.
3. Bit 14 = 1 to enable light pen detect interrupts.
4. Bit 15 = 1 to defer light pen detects interrupts.

This order establishes the mode of light-pen operation in the 2250. It can enable or disable light-pen detects and can enable or defer interrupts when a detect does occur. Deferred detects can be tested by Long Branch/Interrupt orders. Note that execution of a Reset Display command also resets Light Pen mode to disable light-pen detects and defer light-pen interrupts and resets the detect interrupt and detect status bits in the DSW.

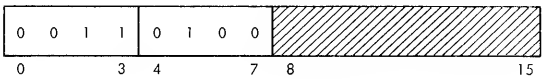
Light-pen switch operation is independent of light-pen detect circuitry. Switch status is sampled once per regeneration cycle. Long Branch/Interrupt orders, by testing the detect status and light pen switch DSW bits, can branch or interrupt as required to support light-pen operations.

A light pen mode is established by the status of bits 12-15 in the Set Pen Mode order. The possible combinations of these bits and the purpose of each combination are as follows:

1. Bits 12-15 = 0 1 X X (Disable Light Pen Detect): Inhibits a detect from setting the DSW detect status bit.
2. Bits 12-15 = 1 0 X X (Enable Light Pen Detects): Permits a detect to set the detect status bit.
3. Bits 12-15 = 0 0 X X or 1 1 X X: Light Pen Detect mode is not changed.
4. Bits 12-15 = X X 0 1 (Defer Light Pen Interrupts): Inhibits a Detect Interrupt from being generated when the DSW detect status bit is set, thereby allowing this status bit to be tested by a Long Branch/Interrupt order.
5. Bits 12-15 = X X 1 0 (Enable Light Pen Interrupts): Permits a Detect Interrupt to be generated when the DSW detect status bit is set. If the detect status bit is set when this Set Pen Mode order is decoded, an interrupt is generated immediately. The detect status bit is reset when the detect interrupt bit is set.
6. Bits 12-15 = X X 0 0 or X X 1 1: Light pen interrupt mode is not changed.
7. Bits 12-15 = 0000, 0011, 1100, 1111 (No Operation): The order is treated as a one-word no-op.

Programming Note: The configuration of all 0's in bits 8-15 of the Set Pen Mode order is reserved for the one-word no-op (GNOP) order.

Start Timer (STMR)



This order prevents the 2250 from using unnecessary storage cycles when executing a short display program, thereby freeing storage cycles for other programs. It is used with a branch order to control regeneration. (The branch order is necessary

to loop from the end of the display program to the beginning, thereby maintaining continuous regeneration without CPU program intervention.) The Start Timer order causes a 25ms timer to be tested. If the timer is running, storage accessing for information following the Start Timer order is delayed. When the timer stops, completing the current 25ms time period, it is restarted, and storage accessing automatically is resumed.

The Start Timer order should be included in each regeneration sequence. The regeneration rate is variable up to a rate of 40cps (25ms frame time) and is determined by the regeneration timer or by the amount of displayed information. (Messages that require less than 25ms to regenerate are displayed at the maximum rate of 40cps.) Note that a flicker-free display image can be obtained with a regeneration rate of 35 to 40cps.

The Start Timer order also allows keyboard interrupts and initiates testing of the light-pen switch. An alphameric or programmed function keyboard interrupt can be generated only during execution of a Start Timer order.

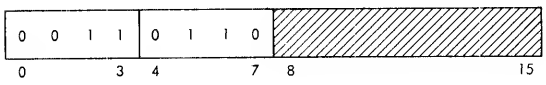
Programming Notes:

1. Failure to use a Start Timer order in a short display program may result in damage to the CRT screen or in variable intensity.
2. The Start Timer order should be used as the first order in a sequence of graphic orders that generates a particular display.

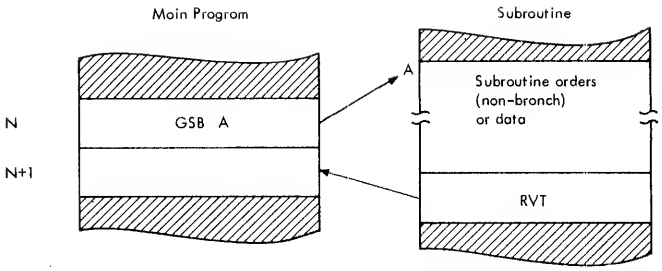
Subroutine Linkage Orders

Subroutine linkage in the display program is accomplished by means of a revert register. Each time a branch order is executed, a return address is saved in the revert register. This address points to the storage location following the location that contains the branch order. The return address is used by two orders: Revert and Store Revert Register.

Revert (RVT)

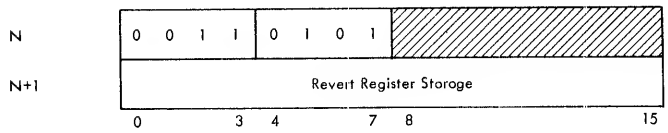


This order causes the revert register contents (the return address) to be loaded into the address register. It is used to return from a single-level subroutine, as follows:

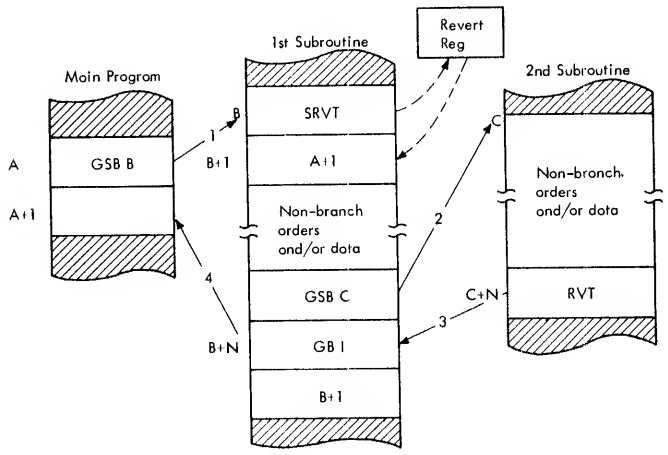


In this example, address N+1 is placed in the revert register as the Short Branch order is executed. This address is then placed in the address register when the Revert order is executed, effecting a return of operations to address N+1. Note that the same function is performed when the revert bit is set in a character data stroke word.

Store Revert Register (SRVT)



This order causes the revert register contents to be placed into storage as the second word of this order. It is used when more than one branch is to be executed before returning to the main program (i.e., for multilevel subroutining). For example, a Store Revert Register order would be executed before a second branch is issued. After the second branch, a third branch, with indirect addressing specified, can be used to return by way of the stored revert register contents as follows:



Since the revert register contents can be modified only by a branch order, interrupted subroutines can be restarted at the point of interrupt.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
E0_	3584	3585	3586	3587	3583	3589	3590	3591	3592	3593	3594	3595	3596	3597	3598	3599
E1_	3600	3601	3602	3603	3604	3605	3606	3607	3608	3609	3610	3611	3612	3613	3614	3615
E2_	3616	3617	3618	3619	3620	3621	3622	3623	3624	3625	3626	3627	3628	3629	3630	3631
E3_	3632	3633	3634	3635	3636	3637	3638	3639	3640	3641	3642	3643	3644	3645	3646	3647
E4_	3648	3649	3650	3651	3652	3653	3654	3655	3656	3657	3658	3659	3660	3661	3662	3663
E5_	3664	3665	3666	3667	3668	3669	3670	3671	3672	3673	3674	3675	3676	3677	3678	3679
E6_	3680	3681	3682	3683	3684	3685	3686	3687	3688	3689	3690	3691	3692	3693	3694	3695
E7_	3696	3697	3698	3699	3700	3701	3702	3703	3704	3705	3706	3707	3708	3709	3710	3711
E8_	3712	3713	3714	3715	3716	3717	3718	3719	3720	3721	3722	3723	3724	3725	3726	3727
E9_	3728	3729	3730	3731	3732	3733	3734	3735	3736	3737	3738	3739	3740	3741	3742	3743
EA_	3744	3745	3746	3747	3748	3749	3750	3751	3752	3753	3754	3755	3756	3757	3758	3759
EB_	3760	3761	3762	3763	3764	3765	3766	3767	3768	3769	3770	3771	3772	3773	3774	3775
EC_	3776	3777	3778	3779	3780	3781	3782	3783	3784	3785	3786	3787	3788	3789	3790	3791
ED_	3792	3793	3794	3795	3796	3797	3798	3799	3800	3801	3802	3803	3804	3805	3806	3807
EE_	3808	3809	3810	3811	3812	3813	3814	3815	3816	3817	3818	3819	3820	3821	3822	3823
EF_	3824	3825	3826	3827	3828	3829	3830	3831	3832	3833	3834	3835	3836	3837	3838	3839
F0_	3840	3841	3842	3843	3844	3845	3846	3847	3848	3849	3850	3851	3852	3853	3854	3855
F1_	3856	3857	3858	3859	3860	3861	3862	3863	3864	3865	3866	3867	3868	3869	3870	3871
F2_	3872	3873	3874	3875	3876	3877	3878	3879	3880	3881	3882	3883	3884	3885	3886	3887
F3_	3888	3889	3890	3891	3892	3893	3894	3895	3896	3897	3898	3899	3900	3901	3902	3903
F4_	3904	3905	3906	3907	3908	3909	3910	3911	3912	3913	3914	3915	3916	3917	3918	3919
F5_	3920	3921	3922	3923	3924	3925	3926	3927	3928	3929	3930	3931	3932	3933	3934	3935
F6_	3936	3937	3938	3939	3940	3941	3942	3943	3944	3945	3946	3947	3948	3949	3950	3951
F7_	3952	3953	3954	3955	3956	3957	3958	3959	3960	3961	3962	3963	3964	3965	3966	3967
F8_	3968	3969	3970	3971	3972	3973	3974	3975	3976	3977	3978	3979	3980	3981	3982	3983
F9_	3984	3985	3986	3987	3988	3989	3990	3991	3992	3993	3994	3995	3996	3997	3998	3999
FA_	4000	4001	4002	4003	4004	4005	4006	4007	4008	4009	4010	4011	4012	4013	4014	4015
FB_	4016	4017	4018	4019	4020	4021	4022	4023	4024	4025	4026	4027	4028	4029	4030	4031
FC_	4032	4033	4034	4035	4036	4037	4038	4039	4040	4041	4042	4043	4044	4045	4046	4047
FD_	4048	4049	4050	4051	4052	4053	4054	4055	4056	4057	4058	4059	4060	4061	4062	4063
FE_	4064	4065	4066	4067	4068	4069	4070	4071	4072	4073	4074	4075	4076	4077	4078	4079
FF_	4080	4081	4082	4083	4084	4085	4086	4087	4088	4089	4090	4091	4092	4093	4094	4095

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